Developing Digital Flood Insurance Rate Maps for Lago Vista

by

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Thesis

Presented to the Faculty of the Graduate School

of The University of Texas at Austin

in Partial Fulfillment

of the Requirements

for the Degree of

Masters of Science in Engineering

The University of Texas at Austin

May 2001

Developing Digital Flood Insurance Rate Maps for Lago Vista

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Acknowledgements

First, I would like to thank my fiancée, Susan Kehnemui, for providing me with the love and friendship that will allow me to conquer any challenge life can provide. Thank you also to my parents, Wayne and Kathy Donnelly, for the encouragement and support I have always received throughout my life.

I would also like to thank my advisor, Dr. David Maidment, for providing the amazing opportunities that exist at the University of Texas at Austin. I am also grateful to Dr. Francisco Olivera for his assistance and support throughout this project.

The study presented in this report was funded by the Lower Colorado River Authority. Their support is gratefully acknowledged. Particular thanks go to Martina Bluem and John McLeod for their work on the study. Thanks also to Jane Huzil at Baker Engineers.

I have also appreciated the help and friendship from the other members of Dr. Maidment's research team, especially Tim Whiteaker, Vicki Samuels, Sarah Stone, Melissa Figurski, and Jordan Furnans.

May 4, 2001

Abstract

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Flood Insurance Rate Maps (FIRMs), managed by the Federal Management Agency, display flood hazards and are used to calculate insurance premiums for the National Flood Insurance Program. This research presents an approach for developing new data included in a DFIRM database, as well as converting existing map data into digital format. A raster base map combining USGS Digital Orthophoto Quadrangles (DOQs) and community developed digital orthophotos was created. Flood hazard zones were redelineated based upon previously determined 100-year and 500-year water surface elevations and recently developed, detailed contour data. This study also demonstrates how a DFIRM data model can be developed to run off an existing geodatabase model. The ArcGIS Hydro data model was extended to contain DFIRM features based upon FEMA's Standard DFIRM Spatial Database. An evaluation of the 100-year floodplain developed using "approximate" study methods (FEMA's Zone A) and a procedure for converting contour data between the vertical datums, NGVD29 and NAVD88, are also presented. The methodology is applied to a study area surrounding Lago Vista, Texas. The results of this research indicate that GIS is an effective environment for developing, utilizing, and storing Flood Insurance Rate Maps.

Table of Contents

List of Tables

List of Figures

Chapter 1: Introduction

1.1 INTRODUCTION

Floods are the most common of natural disasters. For decades, the national response to floods was constructing flood-control projects such as dams, sea walls, and levees, and providing disaster relief to victims. This approach did not reduce losses and did not discourage development in floodplains. Additionally, many destructive floods are too small to be declared a disaster by the President of the United States; meaning that those affected by these "small" floods do not receive any Federal disaster assistance.

The National Flood Insurance Program was created to combat mounting flood losses and escalating costs of disaster relief to the United States Government. Property owners are protected from potential losses through the use of an insurance program that requires a premium to be paid by those most likely to be flooded. A Presidential disaster declaration is not required for participants to receive insurance benefits from the National Flood Insurance Program.

Flood Insurance Rate Maps (FIRMs) show the location of flood hazards and are used to determine the cost of insurance. The Federal Emergency Management Agency (FEMA) has been creating, storing, and updating flood hazard maps, including FIRMs, for National Flood Insurance Program communities since the 1970's. An example of a Flood Insurance Rate Map is shown in Figure 1.1. The goal of FEMA's new Map Modernization Program is to take advantage of new technology to bring greater flexibility, access, accuracy, and efficiency to the process of creating and disseminating flood hazard maps.

Figure 1.1 Flood Insurance Rate Map

A key part of the Map Modernization program is the development of the new Digital Flood Insurance Rate Map (DFIRM) spatial database. This involves the production of new floodplain maps in digital format, as well as converting existing paper maps into digital format. Eventually, the DFIRM spatial database will allow National Flood Insurance Program participants to access Flood Insurance Rate Maps directly through the Internet. This will hopefully increase the ease at which flood insurance is obtained and therefore, increase participation.

The DFIRM spatial database stores the digital data used to produce FIRM maps, as well as the engineering material from the Flood Insurance Study report used to develop the floodplains (e.g., hydrologic and hydraulic models, cross-section profiles, floodway data tables, digital elevation models, and structure-specific information). By storing this type of engineering data digitally, it may be downloaded along with the actual FIRM map.

1.2 OBJECTIVES

The objectives for the DFIRM pilot study were focused on establishing the production procedures and processes of a DFIRM conversion project and the preparation of data for a small study area along the Colorado River. This study was conducted as part of an agreement between the Lower Colorado River Authority (LCRA) and FEMA. The LCRA has agreed to act as a Cooperating Technical Community partner with FEMA, significantly increasing their involvement in the flood mapping process. Because this was one of the initial DFIRM projects attempted, the lessons learned from this pilot effort will be applied to both a larger area encompassing the lower Colorado River basin and the DFIRM effort in general. Additional research was conducted to develop a DFIRM spatial database that works in conjunction with the ArcGIS Hydro Data Model. The pilot study consisted of three major "milestones."

- Milestone 1: DFIRM Base Map and Panel Layout. Develop a work plan and production schedule. Examine the previous engineering flood studies prepared for the study area to determine the water surface elevations and cross-section information available. Conduct a review of the relevant literature and FEMA DFIRM specifications and guidelines. Prepare a DFIRM standards book and distribute it to the project team. Develop a layout of the panels in the study area showing outline and scale.

- Milestone 2: DFIRM Prototype Panel. Develop a GIS version of the 100- and 500-year floodplains using both the flood data collected in Milestone 1 and newly developed contour data from the LCRA. Where water surface profiles are not available, a digitized version of the Flood Hazard Area is utilized. Create a GIS base map of the pilot area in accordance with FEMA DFIRM standards. Overlay the floodplains on the base map to create a flood inundation map. Compare this map with the ones previously created to identify differences between the new and old maps and the reasons for them. Populate necessary attributes for the DFIRM database and construct DFIRM metadata files. Prepare a draft DFIRM for one panel within the study area.

- Milestone 3: DFIRM Final Production. Identify and document errors in the draft DFIRM panel package. Incorporate changes addressing these errors and prepare final DFIRM package for remaining panels. Populate database information and prepare metadata. Submit the final DFIRM package including data files and hard copies of the maps.

1.3 HISTORY

On May 7, 1999, the LCRA signed an agreement with FEMA to act as a Cooperating Technical Community partner. The Cooperating Technical Community program is an initiative by FEMA designed to increase local involvement and responsibility in the flood mapping process. This essentially means that the LCRA will act as the map custodian for flood mapping of the lower Colorado River. One part of the Cooperating Technical Community partnership with FEMA, Task Agreement No. TA-01, requires the LCRA to prepare Digital Flood Insurance Rate Map panels for a small study area.

1.3.1 National Flood Insurance Program

Created in 1968, the National Flood Insurance Program combines mitigation and insurance to reduce future flood damage, reduce Federal disaster assistance expenditures, and save taxpayers millions of dollars. The National Flood Insurance Program is a Federal program enabling property owners in participating communities to purchase insurance against flood losses. This insurance is designed to provide an alternative to disaster assistance and meet the costs of repairing damage to buildings and their contents caused by floods.

The National Flood Insurance Program is administered by the Federal Insurance Administration, and the Mitigation Directorate, and components of the Federal Emergency Management Agency (FEMA). Participation in the National Flood Insurance Program is based upon an agreement between local communities and the Federal Government. This agreement states that if a community agrees to adopt and enforce a floodplain management ordinance designed to reduce future flood risks to new construction within the 100-year floodplain, then the Federal Government will make flood insurance available to most structures within that community. Flood insurance cannot be purchased through the National Flood Insurance Program unless the community in which the structure is located is a participating member of the program.

Community participation is voluntary (although some states require National Flood Insurance Program participation as part of their floodplain management program). If a community does not participate, Public Law 93-234 prohibits Federal officers or agencies from providing any financial assistance for acquisition or construction within the 100-year floodplain. For example, this prohibits loans guaranteed by the Department of Veterans Affairs, insured by the Federal Housing Administration, or secured by the Rural Housing Services.

Additionally, no Federal financial assistance can be provided for the permanent repair or reconstruction of insurable buildings within the 100-year floodplain even if a Presidentially declared disaster occurs.

National Flood Insurance Program coverage is available to all owners of almost every type of walled and roofed building that is predominantly above ground and not entirely over water, if it is in a participating community. Almost all of the nation's communities with serious flooding potential have joined the National Flood Insurance Program. The law only mandates flood insurance for Federal or Federally related financial assistance for buildings within the 100-year floodplain. However, virtually every private mortgage lender requires flood insurance as a condition of receiving a loan, if the structure is in a National Flood Insurance Program participating community.

1.3.2 Lower Colorado River Authority

The Texas Legislature created the Lower Colorado River Authority (LCRA) as a conservation and reclamation district in 1934. The Act was passed in response to the need for a reliable water supply to compensate for the extreme conditions brought upon by Texas droughts and floods. Fifteen major floods hit the Colorado River valley between 1843 and 1935, washing away many dams, homes, and businesses. There also was a significant need for a reliable electric power supply, particularly in rural areas.

The LCRA has six hydroelectric dams on the lower Colorado River, forming what is known as the Highland Lakes. The Highland Lakes and its dams allow the LCRA to provide both flood control and water supply for municipal, industrial, agricultural, and recreational users throughout the LCRA's 10-county statutory district. This district includes Bastrop, Blanco, Burnet, Colorado, Fayette, Llano, Matagorda, San Saba, Travis, and Wharton counties and encompasses the watershed of the lower Colorado River (see Figure 1.2). The lower Colorado River is defined as the portion of the Colorado River below Stacy Dam.

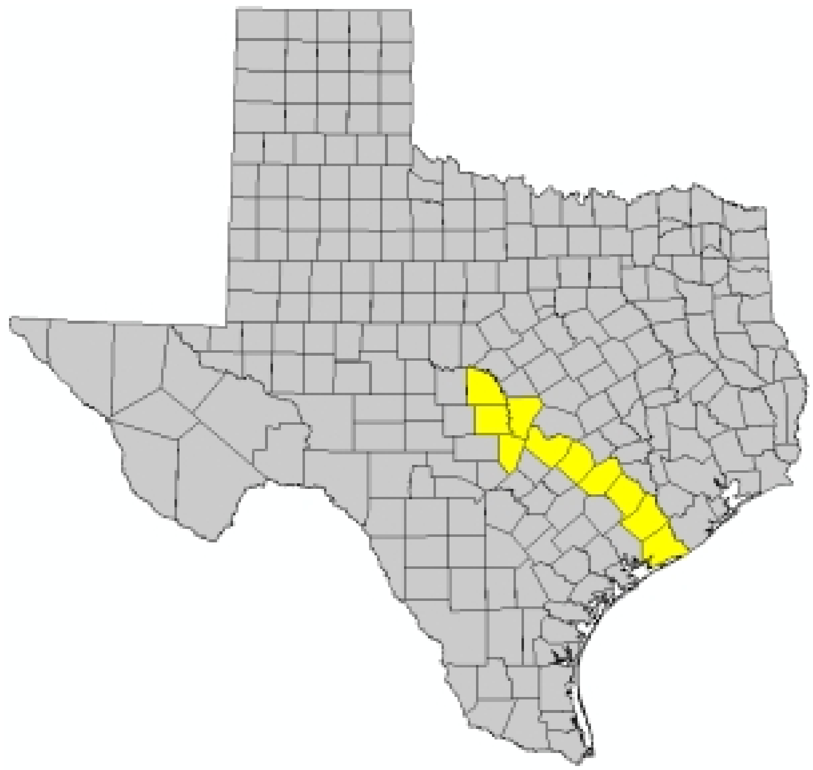


Figure 1.2 Lower Colorado River Authority's Statutory District

The LCRA does not receive state tax money and cannot levy taxes. It operates on revenues mainly from wholesale electric and water sales. Its hydroelectric, coal, and natural gas generating plants provide electricity to more than a million Texans and more than 50 counties through 43 wholesale distributors, including 9 electric cooperatives and 33 cities (LCRA, 1999). It also serves numerous water customers; including cities, rice farmers, and municipal utility districts. The LCRA also provides other services to the region, such as managing floods, protecting the quality of the lower Colorado River and its tributaries, providing parks and recreational facilities to the public, offering economic development assistance, helping water and wastewater utilities, and providing soil, energy, and water conservation programs.

Of the six Highland Lakes, Lakes Travis and Buchanan are the only true water supply reservoirs. Their levels fluctuate depending on water use, evaporation, instream flow requirements, and rainfall. When full, these lakes are very deep, yet they can become quite shallow during drought conditions. In fact, the difference between the historic maximum and minimum lake elevations of Lake Travis is over 96 feet.

The other four Highland Lakes are relatively small and remain virtually full year-round. They can be thought of as "pass-through" lakes because they do not store water for water supply and during high flows, these four lakes function as rivers rather than lakes. Lakes Travis and Buchanan continue to act as lakes, or steady pools, even during the most severe flooding.

1.3.3 Study Area

Task Agreement No. TA-01 specified that a set of DFIRM panels were to be produced for an area near Lago Vista, Texas. This area also includes portions of the cities of Jonestown and Lakeway (see Figure 1.3). These cities are all located in Travis County along the shores of a segment of the Colorado River known as Lake Travis. Lake Travis was formed by the construction of Mansfield Dam in 1941. This dam serves as the only flood-control structure for the lower river basin. The dam has 24 floodgates and is 266 feet high. Lake Travis is over 63 miles long and 4.5 miles wide at its maximum. It covers 18,929 acres and has a capacity of 1,171,000 acre-feet when full. The last major flood event that severely effected Lake Travis and its surrounding cities occurred in 1991.

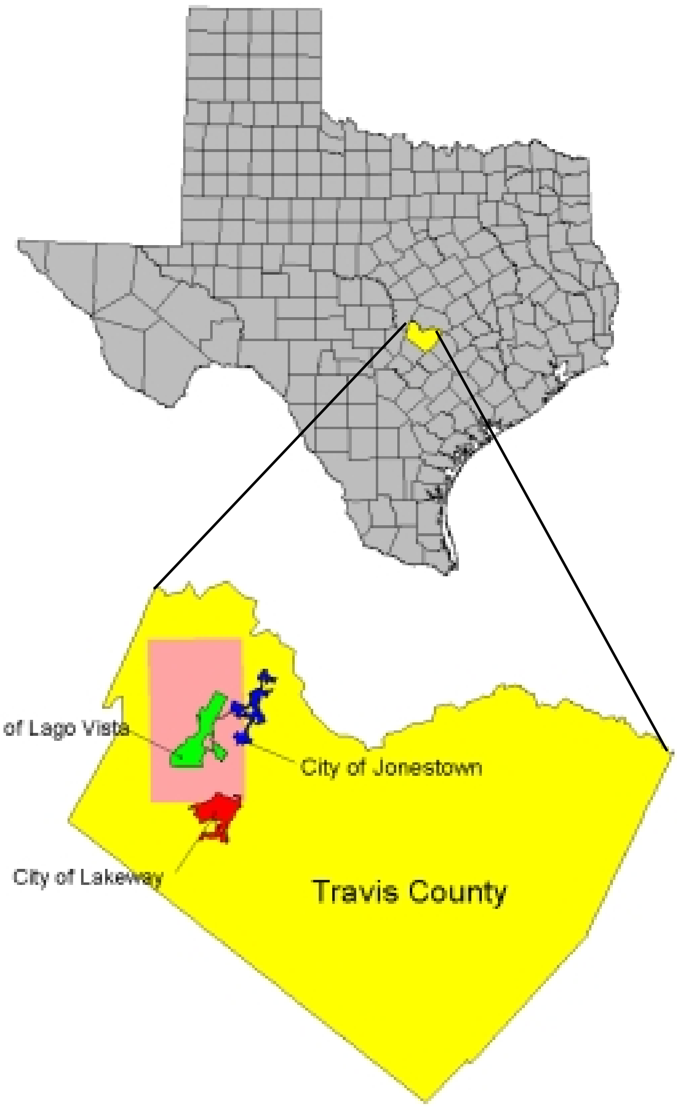


Figure 1.3 Study Area for DFIRM Pilot Study (shown in pink)

All three communities within the study area are currently experiencing considerable population expansion. According to the 2000 Census, Lago Vista is now a city of 4,507 people. This is a significant increase from the 1990 Census count of 2,199. The city of Jonestown has only been incorporated since 1985 and is home to about 800 people, while Lakeway has a population of about 8,000.

The six FIRM panels specified by the agreement include panels 48453C0350E, 48453C0355E, 48453C0360E, 48453C0315E, 48453C0320E, and 48453C0325E, as shown below in Figure 1.4. The first two digits (48) of each panel number correspond to the state that the panel is located in. The next four digits (453C) is the community or county identifier. Combining the two, 48453 is the unique FIPS code for Travis County, Texas. The final four digits represent the panel number.

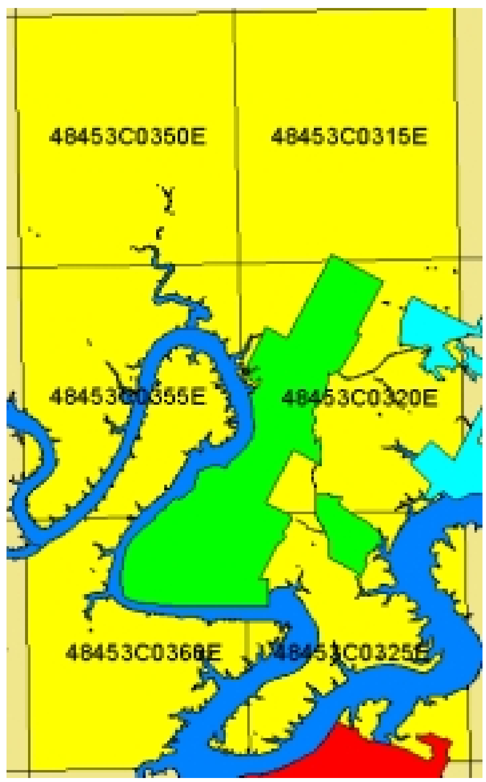


Figure 1.4 FIRM Panels' Location and ID Number

This study area was chosen for several reasons (LCRA, 1999), including:

- Updated digital topographic data has recently become available from the LCRA Phase 1 Contour mapping project.

- Base flood elevations have been previously established. Therefore, no new hydrologic or hydraulic engineering analysis was required under this task agreement.
- The area represents a combination of both urban and rural populations.
- The area has experienced a significant increase in growth since the maps were last updated in 1993.
- The pilot project can easily be expanded to include all of Travis County, since the LCRA and the Capitol Area Planning Council (CAPCO) have recently completed projects to produce FEMA-quality, digital orthophotos.

1.4 OUTLINE

The research described in this thesis shows an approach for converting paper Flood Insurance Rate Maps into Digital Flood Insurance Rate Maps, describes some of the problems that may be encountered, and provides insight into how this data can be stored and disseminated. This thesis is divided into six chapters. Following the introduction, a literature review is presented. The third chapter contains information on the data files that were used in the research. Chapter 4 provides a detailed explanation of the methods used to develop the data required by FEMA. Chapter 5 describes the results of this study. The final chapter presents the conclusions and recommendations for future DFIRM projects. The Appendix contains additional information on the results of this research.

Chapter 2: Literature Review

2.1 INTRODUCTION

Before this research was undertaken, a review of the standards and specifications required for Digital Flood Insurance Rate Maps was performed. It was necessary to determine both what data is required to complete a DFIRM conversion and what standards this data must meet. At the time this research was beginning, FEMA and their Mapping Coordination Contractors were still developing the DFIRM standards. Therefore, several different sources were reviewed and compiled together to form the relevant standards used in this study. Additional literature describing the processes involved in the development of 100-year flood elevations and the National Flood Insurance Program insurance rates was examined.

2.2 STANDARDS IN EFFECT FOR LAGO VISTA PILOT STUDY

In order to avoid having to redo work, a set of standards for the pilot study was agreed upon by the LCRA, FEMA, and FEMA's Mapping Coordination Contractors, Baker Engineers, before data processing began. The seven separate documents used in the pilot study include standards developed by FEMA, the Federal Geographic Data Committee (FGDC), and the U.S. Geological Survey (USGS). The documents are as follows:

- *Base Map Specifications for New Digital Flood Insurance Rate Map Product* (FEMA, 1999)
- *Content Standards for Digital Geospatial Metadata* (FGDC, 1998)
- *Flood Insurance Study Guidelines and Specifications for Study Contractors* (FEMA, 1999)
- *Guide for Preparing Technical Support Data Notebook* (FEMA, 1990)

- *Guidelines and Specifications for Flood Map Production Coordination Contractors* (FEMA, 1999)
- *Specifications for Preparing Maps and Graphics* (FEMA, 1999)
- *Standards for Digital Orthophotos* (USGS, 1996)

2.3 DFIRM REQUIREMENTS AND STANDARDS

Figure 2.1 shows an example of a paper Flood Insurance Rate Map alongside its digital counterpart. One of the most noticeable differences between a FIRM and a DFIRM is the use of a raster image base map for DFIRMs. The default raster image is a USGS Digital Orthophoto Quadrangle (DOQ). When available, vector or raster data that is of better quality (higher resolution or more recently photographed) than the DOQ is preferred (FEMA, 1999). All base map data must be at least as accurate as the 1:12,000 USGS DOQs. 1:24,000 scale base map data, previously accepted by FEMA, no longer meets FEMA's base map accuracy requirements (FEMA, 2000). FEMA is working with the USGS to prioritize the production of DOQ panels in National Flood Insurance Program communities to support DFIRM production so that DOQ imagery will be available for every panel in the country.

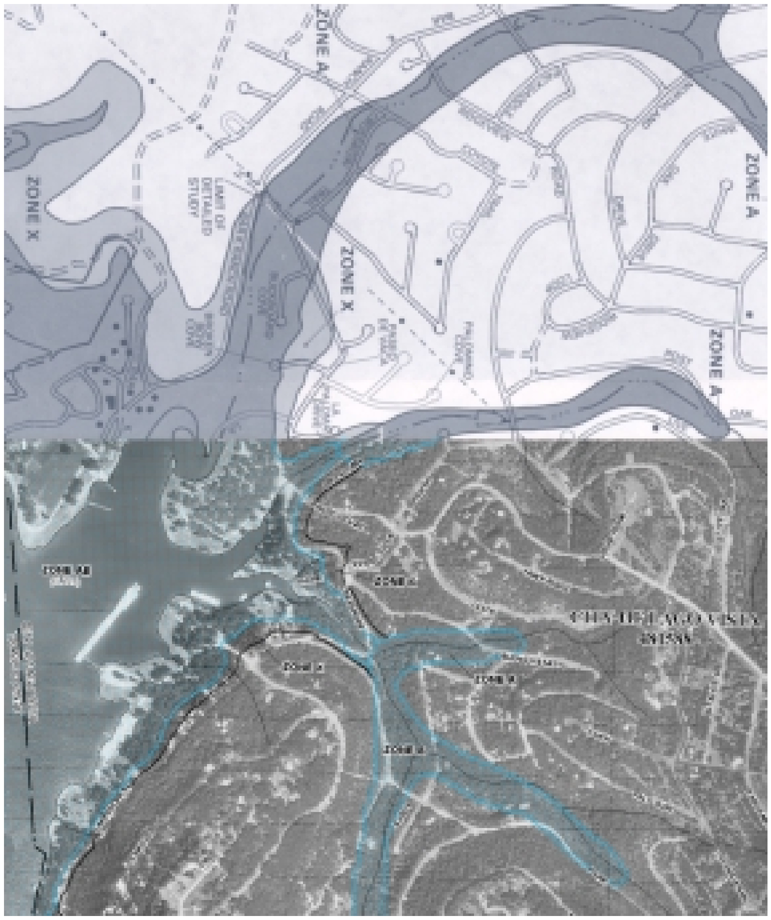


Figure 2.1 FIRM and DFIRM Comparison

In areas where community supplied imagery is of better quality, but does not cover the entire panel, the community's imagery is "quilted" with the DOQ that covers the same area. Similarly, DFIRMs may combine DOQs and vector base map data when lack of uniform base map data or updated information is used to supplement the DOQs.

Base map files contain transportation features (roads, railroads, and airports) for the community. If digital orthophotos are used, these features must be clearly visible. If vector files are used, they must also contain all of the transportation features. Road names need to be shown on the base map no matter which source is used, raster or vector (FEMA, 1999). All data, including the transportation features, raster images, and those features described below, must be separated on documented layers, levels, or by attributes.

FEMA has defined two types of DFIRM spatial databases, the Standard DFIRM Spatial Database and the Enhanced DFIRM Spatial Database (FEMA, 2000). The Standard DFIRM Spatial Database includes all of the features shown on a manually produced paper FIRM panel and the published version of the DFIRM. Some additional information, beyond what is shown on the printed map, may also be included.

In addition to the raster or vector base map, a Standard DFIRM Spatial Database includes the features listed in Table 2.1.

Feature	Description
Flood hazard areas	1% and 0.2% annual chance flood hazard areas and floodways
Hydrographic features	Streams, lakes, shorelines
Transportation Feature Labels	Roads, airports, train tracks, etc.
FIRM panel index	Information on the effective date, size, scale, and location of the panel
USGS 7.5-minute quadrangle index	
USGS DOQ index	
Coastal Barrier Resource System areas	
Political boundaries	Corporate limits, extraterritorial jurisdictions, parks, military reservations, government easements, wildlife preserves
Cross section lines	Lines depicting cross section location
Benchmarks	
Elevation Reference Marks	
Horizontal reference grid lines/ticks	UTM and/or State Plane grid
Structures	Dams, bridges, weirs, etc.
Levees	
Flood Insurance Study	Text/Figures in electronic format
Metadata	Describes data source and constraints

Table 2.1 Standard DFIRM Spatial Database Features

An Enhanced DFIRM Spatial Database is designed to electronically archive all of the data collected during the production of a Flood Insurance Study. The Enhanced DFIRM Spatial Database is also designed to contain features not included in the Standard DFIRM Spatial Database, which support engineering and modeling applications. Most of the enhanced features are not shown on the paper DFIRM. An Enhanced DFIRM Spatial Database may include those features listed in Table 2.2.

Feature	Description
Engineering data files	Stage-discharge curves, rainfall / runoff relationships, etc. for features such as dams, cross sections, or basins
Digital Elevation Model data	
Contour data	
Soil types and Land Use Characteristics	
Basin outlines	Drainage area to a specific point or set of water bodies
Cross section data	N values, station / elevation information, expansion / contraction coefficients, etc.
Stream networks	

Table 2.2 Additional data layers in an Enhanced DFIRM Spatial Database

There are two DFIRM formats, countywide and single jurisdiction. Those prepared in the countywide format show all jurisdictions within a given county on one set of maps, and form the preferred method for DFIRMs. Single jurisdiction or community based DFIRMs show all areas within a single given community's jurisdiction on one set of maps. Although these were the standard for the first 20 years of the NFIP, single jurisdiction maps are now prepared only when lack of adequate base map data or cost constraints prohibit full countywide mapping (FEMA, 2000).

DFIRM map panels are produced at scales of 1 inch equals 500 feet, 1000 feet, or 2000 feet, depending on the density of information, width of floodplains, and detail of the study. For example, it is more appropriate to display an urbanized area, with houses grouped closely together, using a larger map scale, as compared to a rural area where there are very few houses on the panel and a smaller map scale may be more appropriate. A scale of 1 inch equal to 2000 feet generally is used only for areas of approximate study, but may also be used for areas of detailed study with wide floodplains.

Regardless of the scale, DFIRM panels are tiled using a paneling scheme based on USGS 7.5-minute quadrangles or subdivisions thereof. A panel that is to be produced at a scale of 1 inch equal to 2000 feet displays an area the size of one USGS quadrangle sheet. Similarly, a scale of 1 inch equals 1000 feet covers an area the size of a quarter-quadrangle, and a panel produced at a scale of 1 inch equals 500 feet displays an area the size of one-quarter of a quarter-quadrangle, or one-sixteenth of a quad sheet.

After the map scales and layout for a community have been established, the map panels are numbered according to the following system. For a multi-scale DFIRM, the paneling scheme used is able to relate panel number to map scale. A multi-scale DFIRM has panels within a community or county printed at different scales. Panels displayed at a scale of 1 inch equal to 2,000 feet use only numbers divisible by 25. Panels shown at a scale of 1 inch equal to 1,000 feet use only numbers divisible by 5 and panels shown at a scale of 1 inch equal to 500 feet use numbers divisible by one. (FEMA, 2000) This numbering scheme is summarized in Table 2.3. Note that there is no correlation between the numbering scheme used by USGS topographic maps, DOQs, or FIRMs.

Panel numbering for single-scale DFIRMs, those where all panels within a community or county are printed at the same scale, follows sequentially from left to right and from top to bottom. In the case of a single-scale DFIRM, the numbering scheme shown in Table 2.3 does not apply.

Section 4.2 describes an example application of a multi-scale numbering scheme. The following table shows the numbering sequence employed for the three DFIRM map scales.

Map Scale	Acceptable Panel Numbers
1" = 500'	1, 2, 3, 4, 6, 7, 8, 9, 11, 12, 13, 14, 16, etc.
1" = 1,000'	5, 10, 15, 20, 30, 35, 40, 45, 55, 60, etc.
1" = 2,000'	25, 50, 75, 100, 125, 150, etc.

Table 2.3 Multi-Scale DFIRM Panel Numbering Scheme

2.4 METADATA STANDARDS

Metadata, or information describing the content, quality, condition, and other characteristics of a data file, is required for all data submitted to FEMA. Metadata can be used to provide information about an organization's data collection, to provide information needed to process and interpret data received from an outside source, and to properly maintain an organization's database.

The FGDC (1998) has developed an extensive set of standards designed to provide common terminology and definitions for the documentation of digital geospatial data. Every Federal agency is now required to document all new geospatial data it collects or produces, directly or indirectly, using the standards developed by the FGDC.

The FGDC standards establish the names of data elements and groups of elements to be used for these purposes, the definitions of these elements, and information about the values to be provided for the elements. The information included in these standards is designed to fully provide for four general roles that metadata may play. Metadata must describe data availability (what sets of data exist for a given location), fitness for use (does the data meet specific needs), access constraints (who can use a given data set), and data transfer (how is data obtained).

2.5 DEVELOPING BASE (100-YEAR) FLOOD ELEVATIONS

The elevation of the 100-year floodwaters is referred to as the Base Flood Elevation. Areas within the 100-year floodplain are called Special Flood Hazard Areas. FEMA has made the 100-year flood central to the policies of the National Flood Insurance Program. In order to participate in the program, a community must regulate development within the Special Flood Hazard Areas. Additionally, the 100-year flood is the main floodplain shown on Flood Insurance Rate Maps.

FEMA permits the Base Flood Elevation to be calculated in two general ways, detailed and approximate. A detailed method is required by National Flood Insurance Program regulations for proposed developments greater than 50 lots or 5 acres. Detailed studies are generally conducted as part of a Flood Insurance Study but may also be developed using the methodology described in FEMA 265 (FEMA, 1995). Three factors must be determined, either by hand calculations or computer models, to determine a Base Flood Elevation by detailed methods. These factors include: floodplain geometry (topography), flood discharge (hydrology), and flood stage (hydraulics). (FEMA, 1995)

According to the *Flood Insurance Study Guidelines and Specifications for Study Contractors* (FEMA, 1999), acceptable methods for hydrologic analyses of approximate floodplain areas include: the Index-Flood method of statistical analyses; USGS regional regression equations; the Rational Formula; and SCS TR-55. Acceptable approximate methods for hydraulic analyses include normal-depth calculations using Manning's Equation and the use of highway culvert nomographs from *Hydraulic Design of Highway Culverts* written by the Federal Highway Administration (FEMA, 1999).

Costs to conduct a detailed floodplain study can be as high as $8,250 per stream mile (Lear, 2000) and may not always be appropriate. Lear found the approximate methods for delineating floodplains to be far less expensive. He also found the manual techniques involved in a detailed study to be cumbersome and time-consuming. Limited-detail studies use methods with a reduced effort and cost compared to the detailed studies. Cobb (1985) evaluated 2,349 communities in 1984 for the application of limited-detail flood insurance studies. Cobb's study found that approximate study techniques were more appropriate for 1,705 (72.5%) of the communities, while detailed studies were appropriate for 62 (2.6%) communities. Five hundred eighty-two communities were found not to need flood studies.

Recent advances in hydrology and hydraulics using Geographic Information Systems (GIS) have increased the speed and accuracy at which both detailed and limited-detail flood studies may be completed. Dodson (1999) found the use of GIS methods much more efficient than conventional methods in developing topologic data for floodplain studies. The Dodson study used a GIS based program similar to HEC-GeoRAS to develop topology data from a Triangular Irregular Network, and map the resulting floodplain. Conventional methods, requiring a great deal of manual data entry, applied on the same study area were shown to produce similar results, but took almost two and a half times as long to complete. The criteria determining whether a detailed or limited-detailed study is appropriate may have to be revised to consider the benefits that new technologies are bringing to the field.

2.6 INSURANCE RATE DETERMINATION

A number of factors are considered in determining the premium for flood insurance coverage. They include: the amount of coverage purchased; the location, age and design of the building; building occupancy; and the elevation of the building (if it is in a Special Flood Hazard Area). Both the building and its contents can be insured through the program. Table 2.4 contains some information regarding the insurance coverage in the National Flood Insurance Program.

Occupancy Type	Max. Building Coverage	Max. Contents Coverage	Average Coverage	Average Annual Premium
Single Family	$ 250,000	$100,000	$124,300	$570
Non-Residential	$ 500,000	$500,000	$218,600	$1,514

Table 2.4 Cost of Flood Insurance as of May1, 2000 (FEMA, 2000)

FEMA has defined many types of flood hazard zones. Table 2.5 describes each of these zones. A Special Flood Hazard Area is an area subject to flooding by the 1% annual chance (100-year) flood. Areas of Special Flood Hazard include Zones A, AE, AH, AO, AR, A99, V, and VE. The Base Flood Elevation is the water-surface elevation of the 100-year storm.

Flood Hazard Zone	Description	Flood Insurance Mandatory
A	Special Flood Hazard Area with no Base Flood Elevation determined. Detailed hydraulic analyses have not been performed.	Yes
AE	Special Flood Hazard Area with Base Flood Elevations determined	Yes
AH	Special Flood Hazard Area caused by ponding, where average depths are between 1' - 3'	Yes
AO	Special Flood Hazard Area caused by sheet flow on slopping terrain, where average depths are between 1'-3'	Yes
AR	Special Flood Hazard Area formerly protected by a flood control system that has since been decertified. This zone indicates that flood control system is being restored.	Yes
A99	Special Flood Hazard Area that will be protected upon the completion of a new flood control system	Yes
V	Special Flood Hazard Area along the coast subject to additional velocity hazards caused by wave action with no Base Flood Elevation determined	Yes
VE	Special Flood Hazard Area along the coast subject to additional velocity hazards caused by wave action with Base Flood Elevation determined	Yes
X (shaded)	Areas of 0.2% annual chance event (500-year flood); areas of 100-year flood with average depths of less than 1-foot or with drainage areas less than 1-square mile; and areas protected by levees from the 1% annual chance flood	No
X (unshaded)	Areas determined to be outside the 0.2% annual chance floodplain	No
D	Unstudied areas where flood hazards are undetermined, but flooding is possible	Yes

Table 2.5 FEMA Flood Hazard Zones (FEMA, 1999)

Table 2.6 shows how the flood hazard zone in which a building is located can significantly affect the owner's insurance premium. The premiums listed are for $100,000 of flood insurance coverage for a residential single family home.

FEMA Flood Zone	Other Factors	Annual Premium ($)
VE	At BFE	850
VE	1 foot below BFE	2,180
AE	At BFE	431
AE	1 foot above BFE	301
AE	1 foot below BFE	1,251
X	No Basement	351
X	With Basement	441

Table 2.6 Annual premiums for $100,000 flood insurance coverage (FEMA, 2000)

The National Flood Insurance Program's Community Rating System is designed to provide incentives for new flood mitigation, planning, and preparedness activities that protect lives and property in the event of a flood. Community efforts that go beyond the National Flood Insurance Program's minimum standards are rewarded by reducing flood insurance premiums for that community's property owners. The premiums shown in Table 2.6 may be reduced through the Community Rating System activities. These discounts may range from 5 to 45 percent depending on the number of credit points earned. The Community Rating System has 18 floodplain management activities, divided into four general categories, available for credit (FEMA, 1999).

- **Public Information:** This credits community programs that advise people about flood hazards, flood insurance, and ways to reduce flood damage. These activities also provide data for insurance agents.
- **Mapping and Regulations:** This credits programs that provide increased protection to new development. These activities include

mapping areas not shown on the FIRM, preserving open space, enforcing higher regulatory standards, and managing stormwater.

- **Flood Damage Reduction:** Credit is given to communities that have areas in which existing development is at risk. Credit is provided for a comprehensive floodplain management plan, relocating or retrofitting floodprone structures, and maintaining drainage systems.
- **Flood Preparedness:** This credit is given to communities that develop flood warning, levee safety, and dam safety programs.

2.7 SUMMARY

The review of the standards and specifications for Digital Flood Insurance Rate Maps presented above was used as the basis for the development and implementation of a DFIRM conversion project. Knowing which features are required / desired and at what quality is key to providing a product to FEMA that is both acceptable and beneficial. Additionally, knowledge of how insurance premiums are calculated and the financial impact a flood zone designation can have is crucial to fully understanding the importance of developing an accurate Flood Insurance Rate Map.

Chapter 3: Data Description

Many data layers and data sources were used during the development of this DFIRM conversion project. The purpose of this chapter is to describe some of the input data that was used to create the final DFIRM product. The methodology used to develop the final product is described in Chapter 4 of this thesis.

3.1 DIGITAL RASTER IMAGES

Two different digital orthophotos were used to develop the DFIRM base map. Orthophotos combine the image characteristics of a photograph with the geometric qualities of a map. Orthophotos are aerial photographs from which distortion and displacements caused by the camera orientation and terrain have been removed.

The primary USGS Digital Orthophoto Quadrangle (DOQ) is an image covering the size of a quarter-quadrangle (3.75 minutes of latitude by 3.75 minutes of longitude) image defined in the Universal Transverse Mercator (UTM) Projection on the North American Datum of 1983 (NAD83). The DOQ has an overlap that ranges from a minimum of 50 meters to a maximum of 300 meters beyond the extremes of each of the quarter-quadrangle corner points. The pixels of the DOQ have a one-meter ground resolution and are referenced to ground control, so the image may be loaded into a geographic information system and used with other data layers for analysis and geographic applications. Ground control is acquired by using third order class 1 or better survey methods sufficiently spaced to meet National Map Accuracy Standards for 1:12,000 scale products (USGS, 1996). The USGS Digital Orthophoto

Quadrangle (DOQ) program currently has the highest production priority within the National Mapping Program.

Figure 3.1 USGS Digital Orthophoto Quadrangle

The LCRA has independently obtained digital orthophotos over the main stem of the Colorado River, extending 1000 feet to each side of the 100-year floodplain. These images were divided into panels the size of one sixteenth of a USGS quadrangle (1.875 minutes of latitude by 1.875 minutes of longitude). These LCRA orthophotos have a two-foot pixel resolution, 1:16,800 flight scale, and are referenced to a ground control, so that they meet National Map Accuracy Standards (NMAS) for 1:2,400 map scale products. Objects in the photos are shown within four-feet of their true ground position.

Flight scale is the ratio of the length of image on photonegatives to the equivalent distance on the ground. It is roughly equal to the ratio of the focal length of the camera to the height of the aircraft. Map scale is similar, but for the final orthophoto image, which can be enlarged 6-7 times from the flight scale and still be within National Map Accuracy Standards. (Falkner, 1994)

3.2 HYDROGRAPHY

The Capital Area Planning Council (CAPCO) of Texas has created a set of files containing a representation of the centerline of each river or stream that could be seen from 1:2,400 scale and 1:4,800 scale images. The finer scale images were created only within the limits of the City of Austin (CAPCO, 2001). These photos were developed independently of the LCRA's orthophotos described previously. The flight scales for these images were 1:18,000 and 1:30,000, respectively.

The creeks within the city were checked for correctness and modified by the Watershed Protection Department of the City of Austin to connect small gaps and disconnected arcs originating from segments not visible on the aerial photos. To correct these gaps, the department used data describing concrete channel locations, 2-foot contour lines, USGS topographical maps, storm sewer maps, and field investigations (Osborne et al., 2000).

The LCRA had a contractor digitize the outline of all water body outlines and islands visible from the LCRA's 1:2,400 digital orthophotos. It is estimated that 90% of features were plotted within plus or minus five feet of their true geodetic position, and no feature is in error by more than ten feet (ADR, 2000).

3.3 DIGITAL ELEVATION DATA

Three types of digital elevation data were used during this study: two-foot contour data, spot elevations, and a 30-meter Digital Elevation Model (DEM). Only the contour and spot elevation data was used in the DFIRM Pilot Study. Both of these files were derived from the aerial photographs described in Section 3.1. With exception of areas obscured by vegetation, 90% of all contours are accurate within plus or minus two feet and no contour is in error by more than four feet. Ninety percent of all spot elevations are accurate to plus or minus one foot. No spot elevation is in error by more than plus or minus two feet.

The USGS National Elevation Dataset provided the elevation data grid used to supplement the contour and spot elevations for the FEMA Zone A investigation described in Section 4.5.5. The National Elevation Dataset is a seamless DEM that covers the United States at a scale of 1:24,000 and a resolution of 1 arcsecond, or approximately 30 meters. The vertical elevation data are in floating point meters (USGS, 1999).

3.4 Q3 FLOOD DATA

Four different types of digital information about Flood Insurance Rate Maps have been developed. All of these products are digital representations of information contain on paper Flood Insurance Rate Maps. Quality Level 3 (Q3) Flood Data was utilized as part of this study and is essentially a digitized version of the floodplains and political boundaries shown on a paper FIRM. The four different FEMA products are further defined as follows (FEMA, 1995):

- **Q1: Digital Flood Insurance Rate Map - (DFIRM) -** The Digital Flood Insurance Rate Map (DFIRM) is comprised of all digital data required to create the hardcopy FIRM. This includes base map information, graphics, text, shading, and other geographic and graphic data required to create the final hardcopy FIRM product to FEMA standards and specifications. DFIRMs are subjected to community review and approval and are, therefore, the official basis for implementing the regulations and requirements of the NFIP within a community.

- **Q2: Digital Flood Insurance Rate Map - DLG (DFIRM - DLG) -** This product is created by extracting the flood risk data from the DFIRM. The DFIRM-DLG does not include base map information, nor does it include graphic data required to create a hardcopy FIRM. This product is intended to be the primary means of transferring flood risk data depicted by FIRMs to GIS through a public domain data exchange format.
- **Q2: Flood Insurance Rate Map - DLG (FIRM-DLG) -** The FIRM-DLG is a product developed by digitizing and/or scanning and then vectorizing the existing hardcopy FIRM to create a vector representation of flood risks. This product differs from the DFIRM as it is not tied to a base map, is not used to produce a new version of the hardcopy FIRM, and is not subjected to community review. Edge-matching errors, overlaps and underlaps in coverage, and similar problems are not corrected during digitizing or scanning as they are during the DFIRM-DLG production.
- **Q3: Q3 Flood Data -** The Q3 Flood Data is developed by scanning and vectorizing an existing hardcopy FIRM to create a product suitable for viewing or printing. Only certain features from the existing hardcopy FIRMs are vectorized, including: 100-year and 500-year floodplain areas; Coastal Barrier Resources Act areas; political areas; FIRM panel neatlines; and 7.5-minute quadrangle areas.

3.5 BUILDINGS AND DOCKS

Both the building and dock data files were created by digitizing their outlines off the LCRA's 1:2,400 scale digital orthophotos. A contractor hired by the LCRA completed this task. Ninety-percent of the buildings and docks were plotted within plus or minus 5 feet of their true geodetic position as referenced to the nearest grid intersection, and no feature is in error by more than 10 feet.

3.6 ROADS

The Capital Area Planning Council (CAPCO) of Texas has also created a set of files representing the centerline of all named roads within its ten counties. Each centerline was digitized from 1:2,400 scale and 1:4,800 scale images. Data was digitized to imagery with a resolution of 2 feet per pixel so the horizontal accuracy should be at least plus or minus 50 feet. The attributes of this shapefile include a variety of data such as the road name, direction, and address ranges. This information is incomplete in some areas due to the different of levels of progress in each county with regards to their 9-1-1 centerline development. (CAPCO, 2001)

3.7 PARCELS

The parcels dataset was created by the WaterCo division of the LCRA. The data were derived from 1:100 and 1:400 rasterized 1996 Travis County Appraisal District tax maps. The tax plat images have a horizontal accuracy of plus or minus 50 feet, but errors greater than 200 feet do exist (TCTNR, 1998). The parcel polygons were digitized on the computer screen with a scale window of 1:2,400 in ArcView 3.1 and the shapefiles were rectified to match DOQ images.

The purpose of the parcel data is to identify landowners along the lakes and riverfronts of the Colorado River within Travis County. The identification of the landowners will eventually be tied into the creation of a flood warning system for the LCRA. The limits of the data are within 600 feet of the Colorado River. Parcels within 600 feet of the river are attributed with a Parcel_ID number. Those outside of this boundary do not have a Parcel_ID number.

3.8 ARCGIS HYDRO DATA MODEL

The ArcGIS Hydro data model is a data structure used to store and relate geospatial data sets describing water resources and related features. The ArcGIS Hydro Data Model is one of a series of data models, which the Environmental Systems Research Institute (ESRI) is developing in collaboration with partners. It is an object-based model, defined by using classes that possess common attributes and behavior. Objects in different classes can be related using attribute values common to both of the classes (Maidment et al, 2000). This model is designed to operate within and interact with objects defined in the ArcGIS software system. ArcGIS was developed by ESRI and is the newest version of the widely used ArcInfo software.

The ArcGIS Hydro Data Model was developed through collaboration between ESRI and the Center for Research in Water Resources (CRWR) of the University of Texas at Austin. ESRI and CRWR formed a Consortium for GIS in Water Resources, bringing together industry, government and academic partners in a joint effort to build this data model.

The ArcGIS Hydro data model has three main objectives: (1) mapping of water features, (2) linear referencing on the river network, and (3) dynamic modeling of water resources. Linear referencing on the river network refers to building a GIS network model through rivers and water bodies, and then using the addressing capabilities of network models to enable the geographic location of entities on the network. River addressing can be done either by absolute means or by relative addressing. Examples of absolute addressing include river mile or kilometer distances measured upstream from the mouth of a river, or river feet or meters measured upstream or downstream along a particular river reach. Relative addressing, used by the National Hydrography Dataset (NHD), describes location as the percent distance along a particular river reach.

The model is meant to be an *essential* data model, not an *exhaustive* data model. It is intended to include those concepts at the core of water resources and avoid overloading the data model with an excessive number of object classes and descriptive attributes (Maidment et al., 2000). The model structure can be customized and extended by creating new object classes, as shown for this DFIRM study in Section 4.11 of this thesis.

Chapter 4: Methodology

4.1 DATA REVIEW

Before beginning this study, a review of the currently available data was required. The LCRA has spent many years and millions of dollars developing a variety of information about the Colorado River Basin and the communities within it. The LCRA has also assembled other potentially useful data from outside sources including: the USGS, FEMA, Texas Department of Transportation, and the Environmental Protection Agency.

After assessing what data is available, it is then necessary to determine what information is required, what data is not required but is desired, and what data is unwanted in a DFIRM database. Required data are those features that are included in a Standard DFIRM Spatial Database, as described in Table 2.1. Desired features are those that are included in an Enhanced DFIRM Spatial Database, as described in Table 2.2. Several additional features were included in this study that were not included in the Enhanced DFIRM Spatial Database developed by FEMA.

All data used in a DFIRM must not have any use constraints or copyrights, allowing FEMA to freely distribute the information to the public. The data is also required to meet the accuracy specifications described in Chapter 2. These constraints significantly reduced the number of data sets available for use.

It was decided that all DFIRM features that are considered optional would be included if a data set already existed or if it could be easily created. Several of the features required in a DFIRM database were not developed because either the features did not exist within the limits of this study or FEMA agreed to develop the data itself. For example, no railroads or levees are located in the study area and are therefore not included in the dataset. Table 4.1 lists the features intended to be included in a DFIRM study and describes those that were included in the Lago Vista DFIRM Pilot Study.

Feature	**Spatial Database**	**Required**	**Included**	**Reason Not Included**
Raster Base Map Images	SDSB	Yes	Yes	
Flood Hazard Areas	SDSB	Yes	Yes	
Hydrographic Features	SDSB	Yes	Yes	
Transportation Feature Labels	SDSB	Yes	Yes	
FIRM Panel Index	SDSB	Yes	Yes	
USGS 7.5-minute Quadrangle Index	SDSB	Yes	Yes	
USGS DOQ index	SDSB	Yes	Yes	
Coastal Barrier Resource System Areas	SDSB	Yes	No	Not in study area
Political Boundaries	SDSB	Yes	Yes	
Cross Section Lines	SDSB	Yes	No	Not in study area
Benchmarks	SDSB	Yes	Yes	
Elevation Reference Marks	SDSB	Yes	Yes	
Horizontal Reference Grid Lines/Ticks	SDSB	Yes	No	Developed by FEMA
Structures	SDSB	Yes	No	Not in study area
Levees	SDSB	Yes	No	Not in study area
Flood Insurance Study	SDSB	Yes	No	Developed by FEMA
Metadata	SDSB	Yes	Yes	
Engineering Data Files	EDSB	No	No	
Digital Elevation Model Data	EDSB	No	No	
Contour Data	EDSB	No	Yes	
Soil Types and Land Use Characteristics	EDSB	No	No	
Basin Outlines	EDSB	No	No	
Cross Section Data	EDSB	No	No	
Stream Networks	EDSB	No	No	
Buildings	Not Listed	No	Yes	
Docks	Not Listed	No	Yes	
Roads Centerlines	Not Listed	No	Yes	
Parcel Outlines	Not Listed	No	Yes	
Spot Elevations	Not Listed	No	Yes	

SDSB = Standard DFIRM Spatial Database

EDSB = Enhanced DFIRM Spatial Database

Table 4.1 Lago Vista Study Data

4.2 MAP INDICES

Three map indices were included in the DFIRM pilot study. The USGS Quadrangle Index depicts the position of the 1:24,000-scale topographic maps, also known as 7.5-minute quadrangles. A complete index of the state of Texas was obtained by the LCRA from the USGS. This file contains attributes for each quad describing its state, identification number, name, latitude, longitude, and UTM Zone. FEMA requested that all data for this study be supplied in the form of a countywide study. Therefore, all files that were spatially larger than Travis County were reduced in size. In this case, any quad sheet that contained a portion of the county was selected and saved as a new shapefile named *Quad_area.shp.*

Similarly the USGS Digital Orthophoto Quadrangle (DOQ) Index depicts the position of the 1:12,000-scale, 3.75-minute aerial photos distributed by the USGS. A 3.75-minute DOQ is exactly one-quarter of its corresponding 7.5-minute quad sheet. This file contains the same attributes as the USGS Quadrangle Index describing the quadrangle containing the DOQ, as well as the DOQ's code and index number. The original file was also reduced in size to just contain those DOQs containing a portion of Travis County and renamed *Doq_index.shp.*

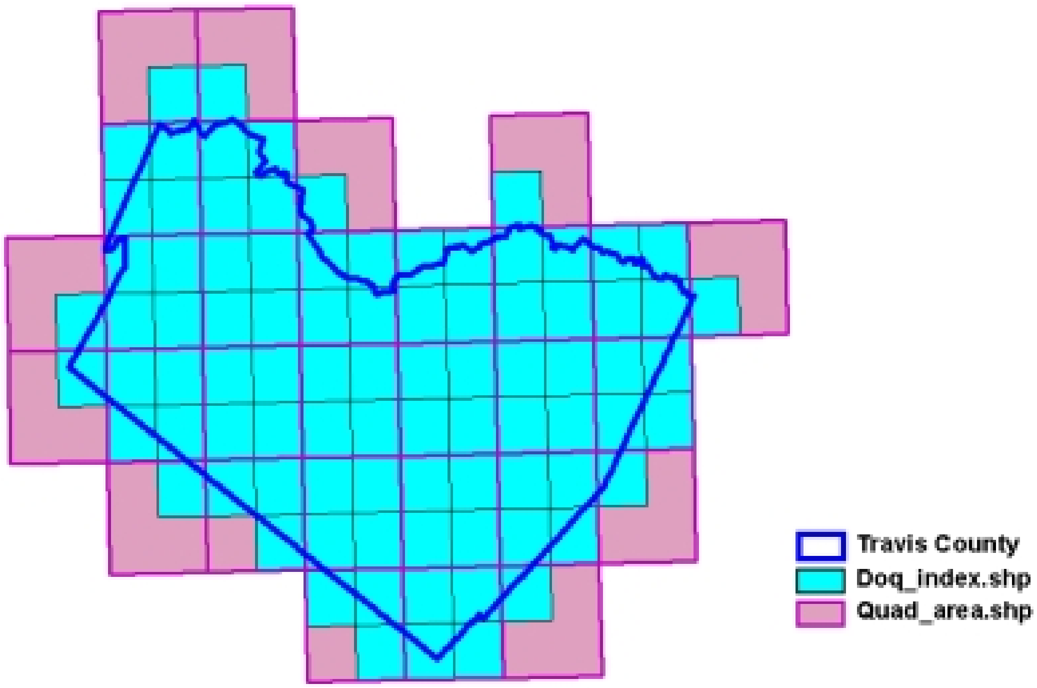


Figure 4.1 USGS Quad and DOQ Index

As described in Section 2.3, DFIRM panels are tiled using a paneling scheme based upon USGS quadrangles or subdivision thereof, depending on the scale. This study utilizes two different map scales. As shown in Figure 4.2, seventeen panels were created at a scale of 1 inch equals 500 feet, and two panels were created at a scale of 1 inch equals 1000 feet. A panel produced at a scale of 1 inch equals 1000 feet displays an area the size of one DOQ. Therefore, seventeen of the panel neatlines had to be created by dividing the DOQ panels into quarters.

This was completed by first reprojecting the polygon shapefile representing a DOQ index from the Texas State Plane coordinate system to geographic coordinates. This is done because in Texas State Plane coordinates, the map neatlines appear curved. However, they form perfect rectangles when shown in geographic coordinates. This new shapefile was then exported to an

AutoCAD ASCII Drawing Interchange (DXF) file using SHAPEDXF. SHAPEDXF is a stand-alone program that is installed with the ArcView 3.2 program files.

AutoCAD was then used to quarter the appropriate DOQ panels by snapping to the midpoints of the DOQ panel outlines. The AutoCAD file was then converted back into a shapefile by simply opening the drawing file *neatlines.dwg* in ArcView and saving the theme as a shapefile. In order to view AutoCAD files in ArcView, the extension *CAD Reader* must be loaded. A polyline shapefile is created, which must then be converted into a polygon shapefile. This is done using an ArcView extension developed by the LCRA. The resulting file was then projected back into Texas State Plane coordinates. It should be noted that the new ArcGIS 8.1 editing tools could be used to snap to the midpoints of shapefiles without having to use AutoCAD.

Additional information about each FIRM panel, including its panel number, effective date, and the latitude and longitude of the northwest and southeast corners, was then added to the attribute table. Appendix B and C contains Unified Modeling Language (UML) diagrams that define attributes of each DFIRM feature created in this study.

The two panels, 0350 and 0315, that were to remain at a scale of 1 inch equal to 1,000 feet retained their original panel number, a multiple of five. Figure 4.2 shows how the panel layout and numbering scheme have changed from the original FIRM to the new DFIRM. New panel numbers had to be assigned to each of the seventeen panels shown at 1 inch equal to 500 feet. These numbers were assigned based upon the numbering scheme described in Section 2.3. The seventeen smaller map panels were assigned the four numbers immediately preceding the "parent" panel number. For example, Panel 355 was split into four smaller panels that were assigned new panel numbers of 351, 352, 353, and 354 from left to right and top to bottom.

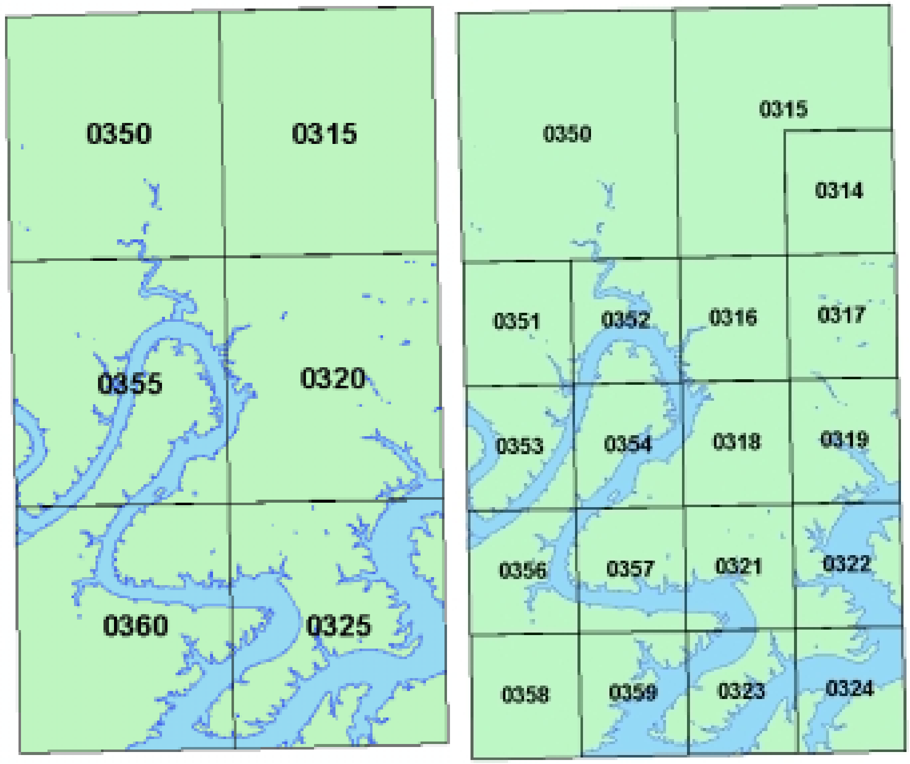


Figure 4.2 FIRM (left) and DFIRM (right) Panel Layout and Numbering Scheme

4.3 RASTER BASE MAP IMAGES

A "quilted" photo image base map was created for this project, enabling the highest resolution data to be shown at every location. The LCRA acquired digital orthophotography having a pixel resolution of 2 feet, which extends 1000 feet beyond the 500-year floodplain of the Colorado River. Because this data does not cover the entire area displayed on the DFIRM panels, Digital Orthophoto Quadrangles (DOQs) with a pixel resolution of one meter (3.28 feet) were used to fill in the remaining gaps. In addition to merging the images together, the DOQ had to be stripped of color to match the black-and-white aerial photos. Figure 4.3 shows one of the original DOQ's used in this study and one of the LCRA's aerial photos. The LCRA aerial photo corresponds to the portion of the DOQ within the yellow outline. The following is a description of the procedure used to quilt the DOQs and the LCRA's aerial photos.

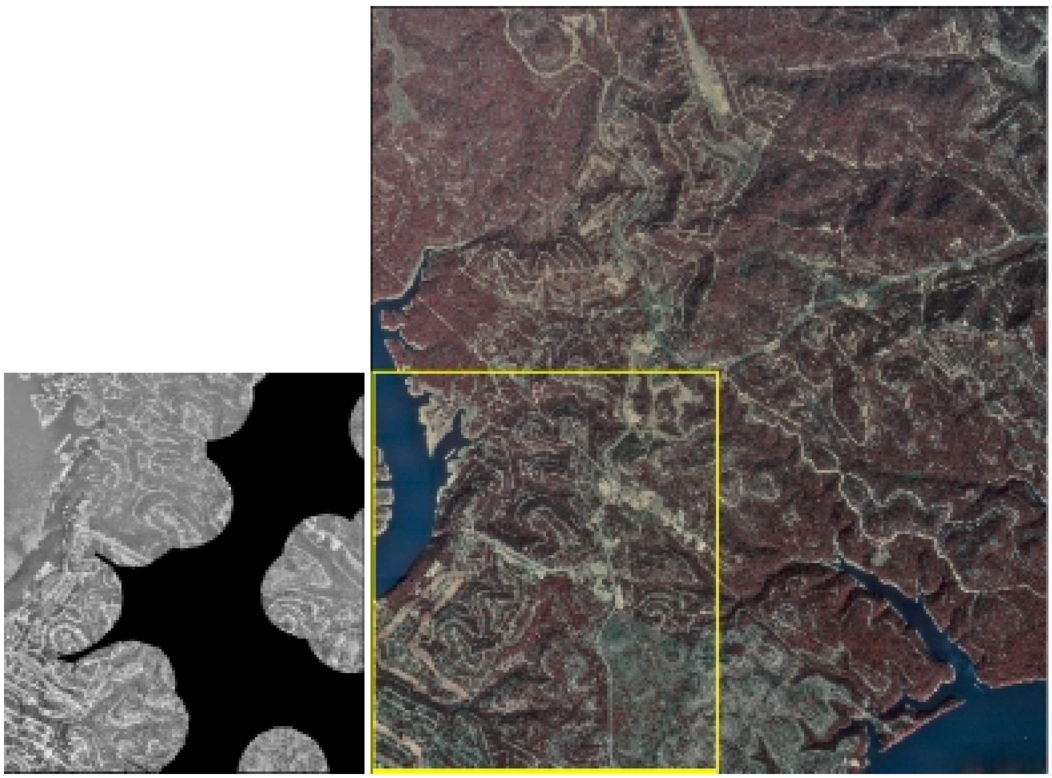


Figure 4.3 LCRA's Aerial Photography (left) and USGS DOQ (right)

In order to create individual base maps for each DFIRM panel, it was necessary to first develop the panel neatlines described in the Section 4.2. The *imagegrid* function in ArcInfo 7.2 was then used to convert both the DOQs and the aerial photos from Tag Image File Format (TIFF) images to ArcInfo Grids.

As can be seen in Figure 4.3, the portion of the LCRA aerial photo greater than 1,000 feet from the floodplain is shown as black. A black-and-white image, be it a grid or a TIFF, has each image pixel assigned a value ranging from 0 to

255. Every value is associated with a shade of gray; 0 represents black and 255 represents white. The image pixels in the LCRA aerial photo that were not photographed appear to be all black (value 0), but actually range from 0 to 12. In order to merge the two photos, these cells must all be converted to a NODATA value. The following ArcInfo commands retains the value of all cells greater than 12 and assigns all others the value NODATA (note: words in all caps represent generic file names):

Grid: **if (grid>12) NEWPHOTOGRID = PHOTOGRID**

Grid: **endif**

When the *imagegrid* command is executed, color images such as the DOQ are converted into three different color bands (red, blue, and green). Each of these bands is also assigned values between 0 and 255 and can be treated as a separate black-and-white image. Therefore, both the blue and green bands were erased and just the red band was merged to the LCRA's aerial photograph. The red band was chosen as the best option after comparing the images that result from converting each of the three bands to a black-and-white image. Before merging the grids, it is necessary to better match the shading of the black-and-white images. Figure 4.4 shows what can result if this step is not completed.

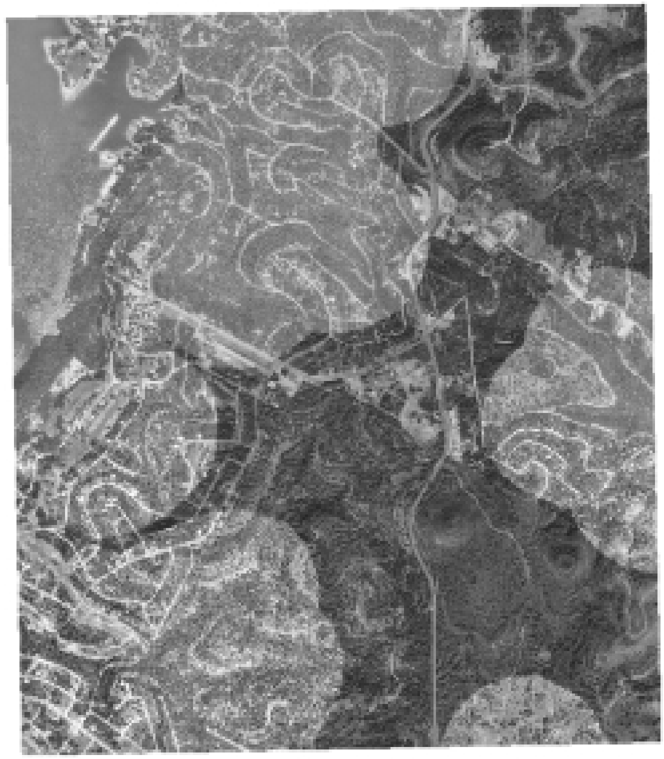


Figure 4.4 Merged Images Without Intensity Adjustment

The mean value of both the aerial photo grid and the red band of the DOQ grid are determined by using the *describe* command. After determining the difference of the two means (DIF), the cells of the DOQ grid are adjusted using the following commands:

Grid: **if (DOQ <= (255 - DIF)) NEWDOQ = DOQ +DIF**

:: elseif (DOQ > (255 - DIF)) NEWDOQ = 255

:: endif

The resulting grid was then checked to see if the shading of the two images matches well. If not, the DIF value is adjusted and the step is repeated. Using the mean grid values to define the initial DIF value does not always lead to a perfect result, but is a good starting point. Panels that display large bodies of water tend to have a lower average grid value, since water is shown as a darker shade of gray than the majority of the land. The following example is for DFIRM panel number 315, as shown in Figure 4.2. The original DOQ image has a mean pixel value of 107, while the LCRA's digital orthophoto has a mean pixel value of 126. Therefore, the DIF value was chosen as 19 and the image was adjusted using the commands described above. This produced a new image that was still too dark. The DIF value was then adjusted to 15 and a new image that closely matched the intensity of the LCRA's image was produced.

The grids can now be merged together. At this point the cell size must be specified so ArcInfo does not reduce the resolution of the LCRA aerial photos to match that of the DOQ. Unless specified, ArcInfo always uses the larger cell size of the two input grid files for its calculation. The *merge* command is then used to combine the two grids together. Only NODATA cells in the first grid specified after the *merge* command can be overwritten. The second grid's values can fill in NODATA cells of the first grid or add values to any cells outside the limits of the first grid. The following command lines will merge two grids together as described above:

Grid: **setcell NEWPHOTOGRID**

Grid: **MERGEDGRID = merge (NEWPHOTOGRID, NEWDOQ)**

The resulting grid was then clipped to its corresponding neatline and converted back to a TIFF file. This is done in ArcInfo by making each individual panel into its own shapefile (as described in Section 4.2), converting the shapefiles into coverages, and using the *gridclip* command to clip the grid. The following command line is then used to convert the final grid into the TIFF image shown in Figure 4.5:

Grid: **gridimage CLIPPEDGRID gray NEWIMAGE tiff**

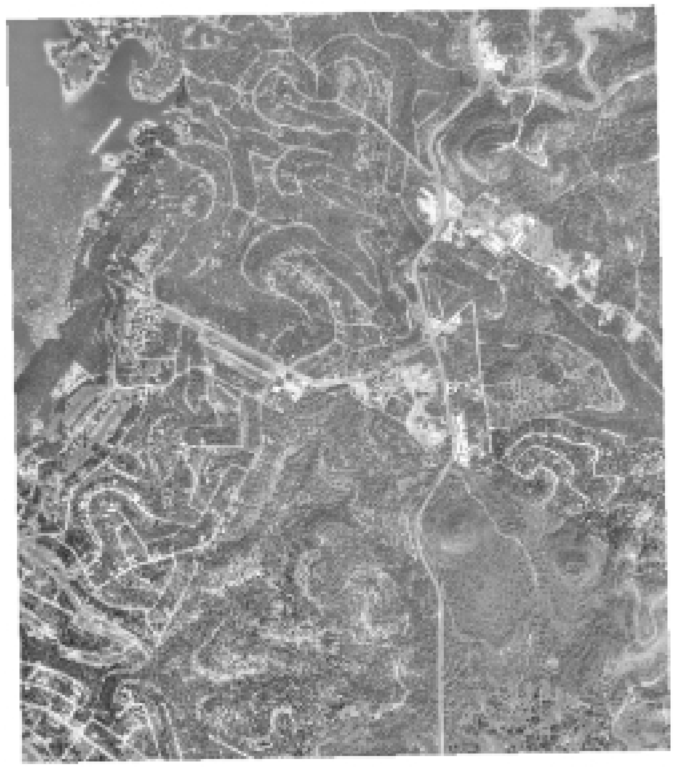


Figure 4.5 Quilted Base Map

4.4 HYDROGRAPHIC FEATURES

Two representations of hydrographic features were produced for this study. One file, *Hydrography_Area.shp*, represents bodies of water that are large enough to be depicted by shorelines as polygons. This file is similar to those features found in the *Waterbody* class of the ArcGIS Hydro data model. A subcontractor digitized the features contained in this file from the LCRA's aerial photographs. Additional attributes were added to the features during this study. These attributes include the name of the feature, the source of the data, the National Hydrography Dataset (NHD) reach number, and the year in which the shoreline is defined.

A second file, *Hydrography_Line.shp*, represent both the shorelines depicted in the file *Hydrograpy_Area.shp*, and the centerlines of all the creeks, streams, rivers, etc. within the panel as polylines. This file is similar to those features found in the *Hydro Edge* class of the ArcGIS Hydro data model. The shorelines were developed by converting *Hydrography_Area.shp* from a shapefile to a coverage and then using the *Build* command in ArcInfo.

The Capitol Area Planning Council (CAPCO) of Austin, Texas developed the centerline features by digitizing off their own set of aerial photographs. The two groups of features were then merged, clipped to the county, annotated, and attributed. These attributes include the name of the feature, the source of the data, the NHD reach number, and the year in which the shoreline is based upon. Figure 4.6 shows both the polygon features (light blue) and the linear features (dark blue) developed for Travis County.

Figure 4.6 Hydrographic Features

4.5 FLOOD HAZARD AREAS

The flood hazard areas in this study can be characterized into two general groups: those floodplains determined in a detailed study and those that were not. The 1% annual chance event or 100-year flood, also known as the Base Flood, is the flood event that has a 1% chance of being equaled or exceeded in any giving year. FEMA defines the Special Flood Hazard as the area subject to flooding by the 1% annual chance flood and has defined eight unique areas for the Special Flood Hazard.

Zone A is defined as a Special Flood Hazard Area for which no Base Flood Elevation has been determined. A Base Flood Elevation is the elevation of the 1% annual chance event. Zone A can therefore be considered a floodplain for which a detailed study was not conducted. Zone AE is a Special Flood Hazard Area for which base flood elevations have been determined. See Table 2.5 for more information on the definition of flood hazard zones.

FEMA has given Zone X two different definitions as described in Table 2.5. One is defined essentially as areas inundated by the 500-year flood, while the other refers to areas outside the 500-year floodplain. These two definitions are quite different and are treated as separate zones throughout this document. The area impacted by the 500-year flood is referred to as Zone X (shaded) or Zone X500, while the area unaffected by the 500-year flood is referred to as Zone X (unshaded) or simply Zone X. Both Zone AE and Zone X500 are zones for which a detailed study has been conducted.

This study did not involve restudying areas without a detailed study or recomputing flood elevations of Zones AE and X500. However, the floodplain extent of these two zones was redelineated using the 2-foot contour data developed by the LCRA and the flood water surface elevations on the existing FIRM maps. The water surface elevations of the 100-year and 500-year flood are 716 and 728.5 feet above mean sea level. Since this is a lake with negligible velocity, even during a major flood event, the same elevation is used throughout the study area.

4.5.1 Zone A

A digital version of Zone A was developed using the Q3 Flood Data available through the FEMA Map Service Center. Data can soon be ordered through the web site http://www.fema.gov/MSC/ordrinfo.htm. Q3 Flood Data is described in greater detail in Section 3.4. A shapefile was created from the polygons with the value "A" in the "Zone" attribute field of the Q3 Flood Data coverage. In its original form, city limit lines and FIRM panel neatlines are embedded in the Q3 data. These were removed using ESRI's Geoprocessing Wizard to *dissolve* features based on the “Zone” attribute.

The *dissolve* process is used to remove boundaries between adjacent polygons that have the same values of a specified attribute. Figure 4.7 shows the original Q3 file; Figure 4.8 shows the resulting file after dissolving the features based upon the "Zone" attribute. The gaps that appear between the tributary and the lake in the upper right corner of Figures 4.7 and 4.8 were created when selecting the portions of the Q3 data that intersect the study area. The missing features do not fall within the study area and are therefore not included.

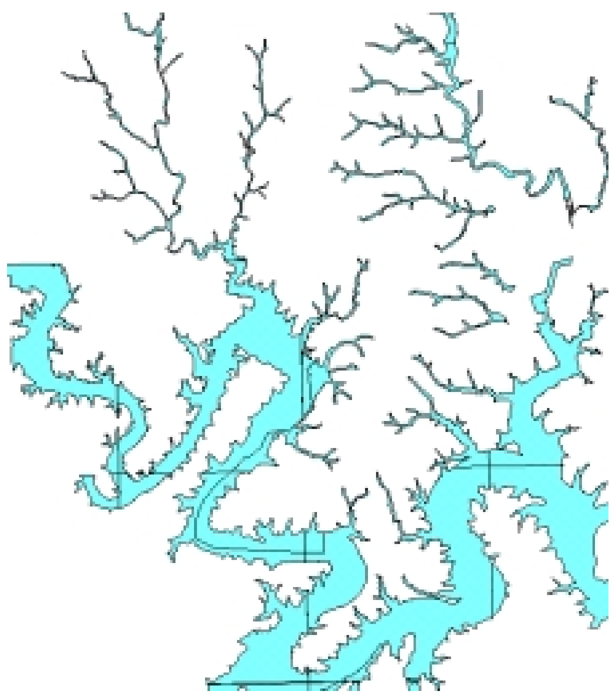


Figure 4.7 Unedited Q3 Flood Data

Figure 4.8 Dissolved Q3 Flood Data

The Q3 file within the study area was attributed without a distinction between the Zones A and AE. Zones A and AE are both areas inundated by the 100-year storm, but only Zone AE has been studied in enough detail to determine the Base Flood Elevation. Only Zone A was attributed in the original Q3 shapefile. Therefore, the “closure line” that marks the division between the two zones had to be digitized from the paper FIRM maps using AutoCAD.

The dissolved Q3 shapefile was first reprojected from Texas State Plane coordinates into State Plane coordinates in order to match the projection of the paper FIRM map. The file was then exported to an AutoCAD DXF file using the SHAPEDXF program. The DXF file was opened in AutoCAD and used to calibrate a digitizing board. The "closure lines" were then digitized off the paper maps. These lines were saved as the AutoCAD file *floodgutter_utm.dwg* and opened in ArcView.

After reprojecting the file back into Texas State Plane coordinates, the new file, *floodgutters_sp.shp,* was used as a guide to split the Zone A polygons into both Zones A and AE. The new zones were then compared to those on the paper FIRM panels to see if the road to floodplain relationship is consistent and adjustments were made where necessary. The comparison was easily accomplished by printing out the new flood zones and base map at the same scale as the paper maps, and using a light desk to compare the road and floodplain locations. This comparison led to the conclusion that the Q3 data was consistently 40 feet off from the paper FIRMs. Therefore, all of the new features representing Zones A and AE were shifted 40 feet west. Figure 4.9 displays the resulting shapefile.

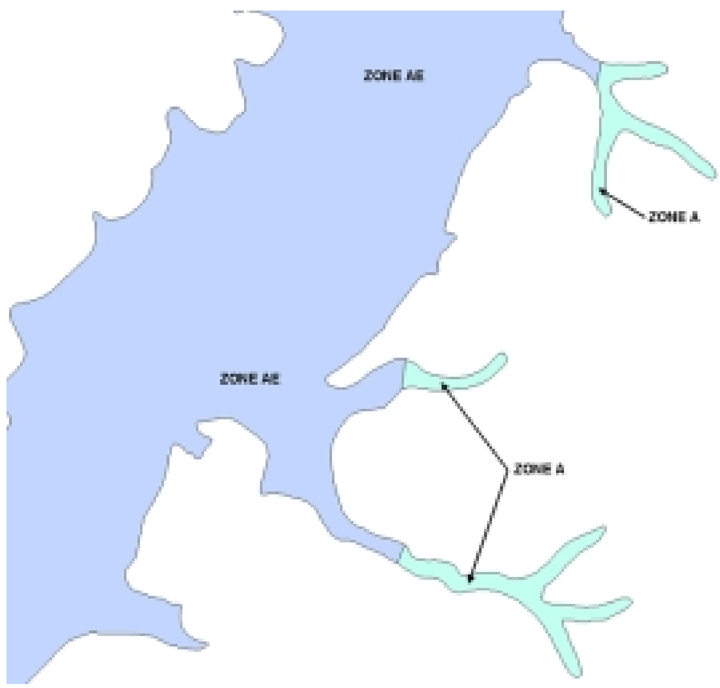


Figure 4.9 100-year Flood Plain Zone

The portion of the file shown in Figure 4.9 representing Zone AE was then deleted, because the floodplains for the 100- and 500-year events were to be delineated using the newly available contour data. The flood elevations for Zones AE and X500 were determined to be 716 feet and 728.5 feet using the National Geodetic Vertical Datum of 1929 (NGVD29) in a previous Flood Insurance Study (FEMA, 2000). Because Lake Travis acts as a level pool during a flood, the floodplains can be developed by simply querying the contours for elevations 716 and 728.5.

4.5.2 Zones AE and X500

There were two main challenges in developing Zones AE and X500. First, the contours are 2-foot contours. This means that contours 716, 728, and 730 are readily available, but not 728.5. Secondly, the contour data provided by the LCRA aerial photography is based upon the North American Vertical Datum of 1988 (NAVD88), while the Flood Insurance Study used to determine the 100- and 500-year flood elevations was based upon the National Geodetic Vertical Datum of 1929 (NGVD29), which is still used by FEMA.

A vertical datum is a way of defining the mean sea level of the earth. Elevation is defined as the vertical distance between the mean sea level and the point of interest. Mean sea level is a surface of constant gravitational potential and is also referred to as the Geoid. Several different Geoids have been developed, but the two most commonly used are the National Geodetic Vertical Datum of 1929 and the North American Vertical Datum of 1988.

The contour line that represents NAVD88 elevation 728.5 was generated by first creating a triangulated irregular network, or TIN, from the contours 726, 728, 730, and 732. A TIN is a way of representing a surface using triangular facets. The vertices of these facets are defined by points on vector contour lines.

TINs are the most commonly used structure for modeling continuous surfaces using a vector data model. The TIN was created in ArcView by using the *3D Analyst* extension. A query was run on the contour shapefile, selecting the desired contour lines. The command, *Create TIN From Features*, was then selected from the Surface menu. Figure 4.10 shows the options selected in the Create new TIN menu.

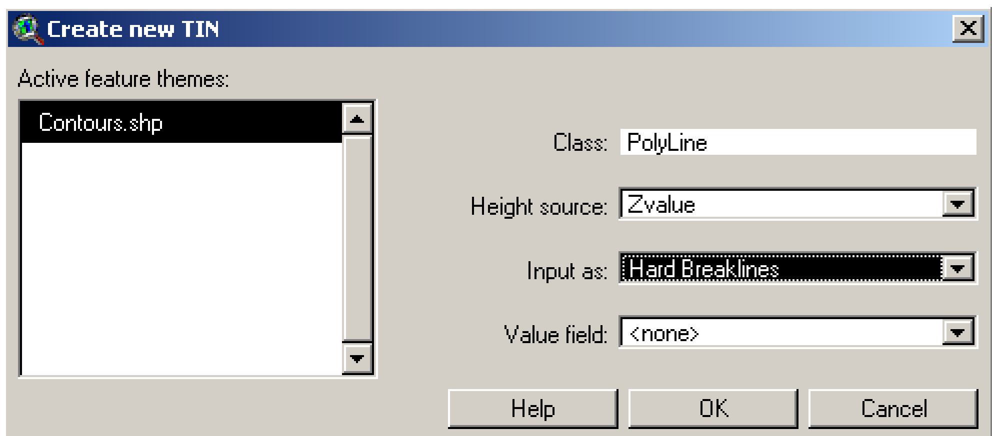


Figure 4.10 Creating A New TIN

After creating the TIN, the 728.5 contour was easily created using *3D Analyst*. The new TIN was made active and then the *Create Contours* command was selected from the Surface menu. When prompted for the contour parameters, the contour interval was set to 1000 and the base contour was set as 728.5. The resulting contour was saved as a new shapefile called *X.shp*.

FEMA decided that the second issue, mismatched vertical datums, was not a problem and the portion of this study submitted to FEMA did not address this issue. An independent investigation was conducted to reconcile the NGVD29 and NAVD88 data differences and is discussed in Section 4.5.4. The remainder of this section discusses how the flood zones submitted to FEMA were created.

The contours representing elevation 716 were selected and saved as a new shapefile called *AE.shp*. Both of the files *X.shp* and *AE.shp* (see Figure 4.11) were clipped to the study area, and lines were drawn to close the ends of the lines. The clipped file was then converted to an ArcInfo coverage using the *shapearc* command in ArcInfo 7.2.

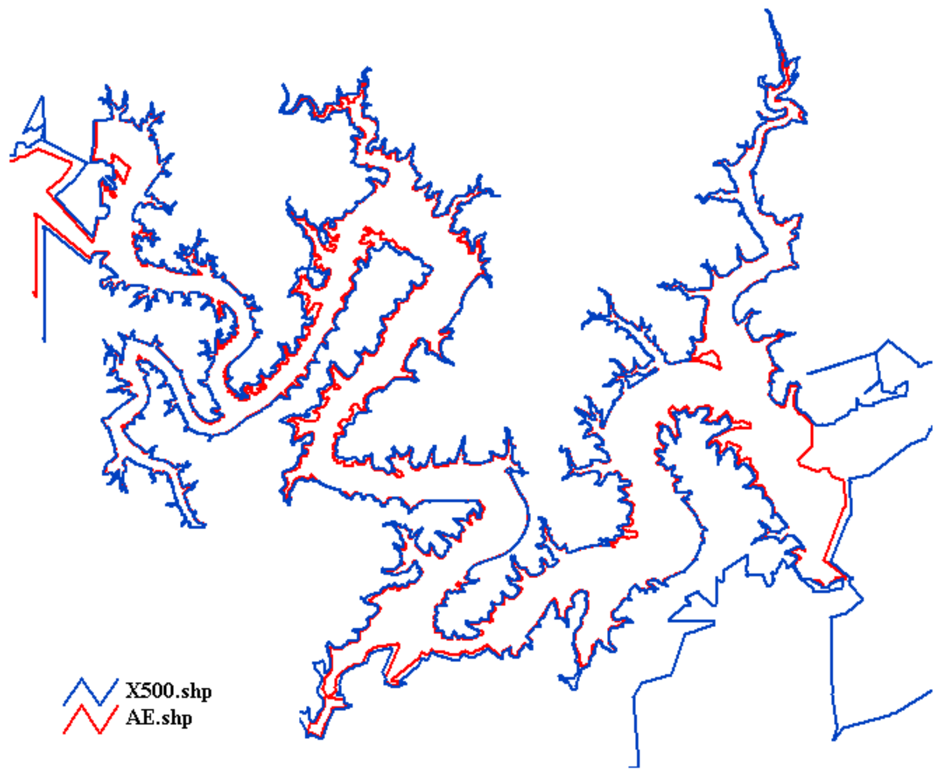


Figure 4.11 Contours for Elevation 716 (AE) and Elevation 728.5 (X500)

The *clean* command was then executed to create final region topology and remove redundant lines. At this point both of the files, *xcov* and *aecov1,* are polylines. The *build poly* command was used to define polygon topology for each of the coverages. The resulting polygons form the Flood Hazard Zones AE and X500 and are shown in Figure 4.12.

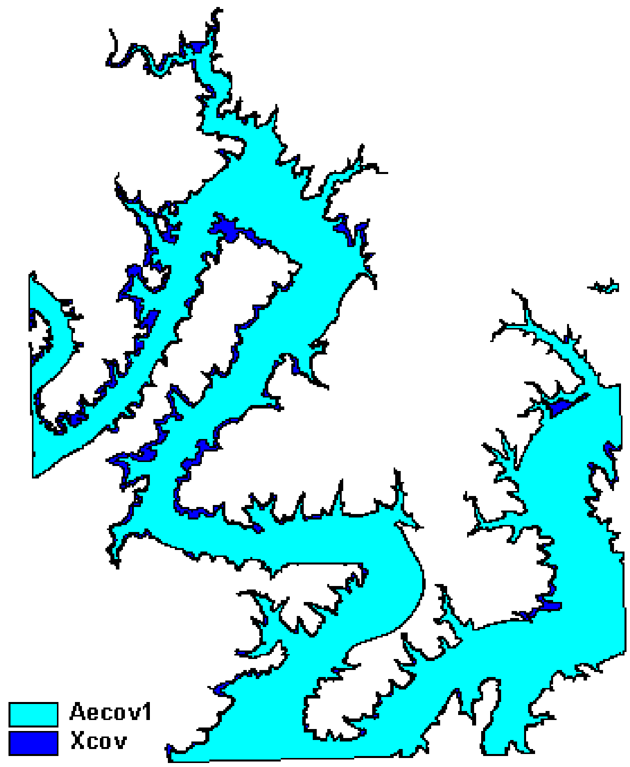


Figure 4.12 Contour Polygons for Floodplain Zones

These polygon coverages were opened in ArcView and saved as shapefiles. The *Union* process of the GeoProcessing Wizard was then used to combine the two themes into a new file named *union1.shp*. The *Union* process produces a new theme containing the features and attributes of the two input polygon themes. The features that represent the AE zone were then erased from *union1.shp*, leaving the portion of Zone X500 that does not overlap Zone AE (see Figure 4.13).

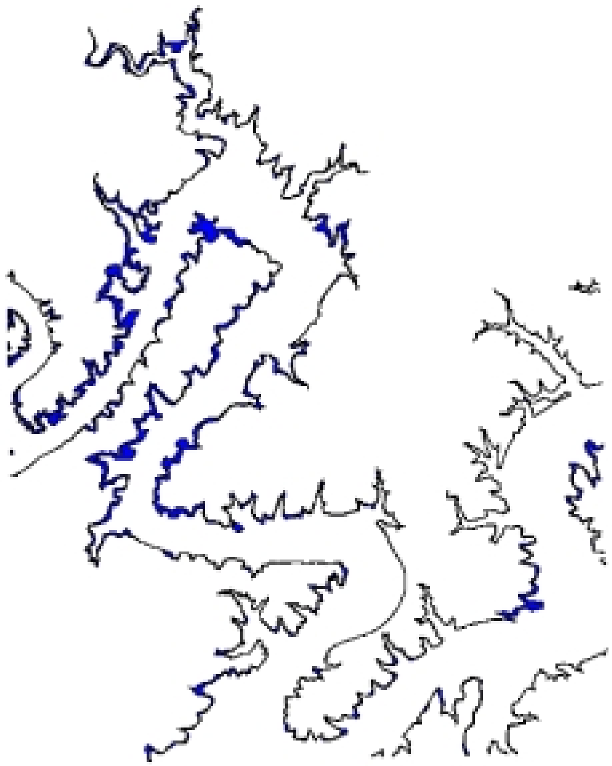


Figure 4.13 Zone X500

The *Merge* process of the GeoProcessing Wizard was then used to merge *Union1.shp* to the shapefile representing Zone AE. The resulting file, *AE_X.shp* contains features representing the Zones X500 and AE. The attribute table of this file was then edited to contain the field "Zone," which was then populated with the correct value (X or AE).

4.5.3 Final Processing

The two files, one containing Zones AE and X500 and one containing Zone A, needed to be joined. Because they were developed from different sources, there were some matching problems that needed to be resolved. The "closure lines" that mark the dividing line between Zones A and AE were used to cut Zone AE. Where necessary, Zone X500 was modified to match up correctly with the A zones. The editing tools of ArcGIS 8.1 were used to make these modifications because of their accuracy and ease of use. The two files were then joined together using the *Merge* process of the GeoProcessing Wizard creating a file called *ae_axmerge.shp*.

Finally, one last zone needed to be created. The Zone X, defined as areas determined to be outside the 0.2% annual chance floodplain, covers all other areas. In order to create this zone, a new theme was created by drawing a rectangle large enough to cover the entire study area. This theme was then intersected with *ae_axmerge.shp* and saved as a theme called *temp.shp.* The features of the intersected theme that coincide with *ae_axmerge.shp* were then erased. The resulting file is shown in Figure 4.14.

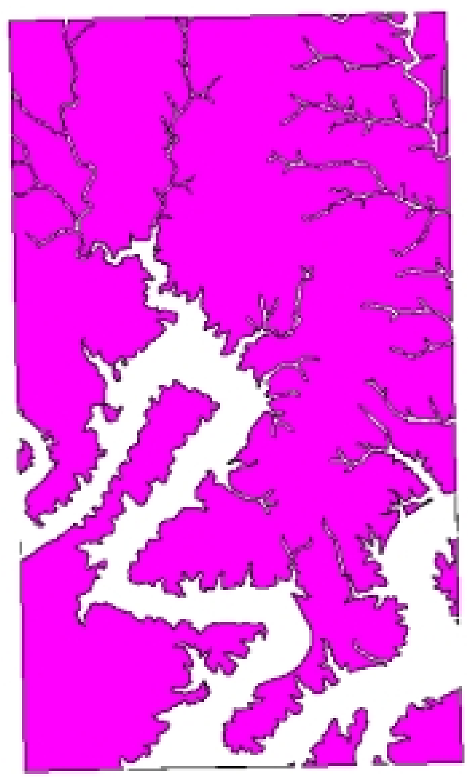


Figure 4.14 Zone X

Finally, *temp.shp* and *ae_axmerge.shp* were merged together and saved as a file called *flood_hazard_area.shp* (see Figure 4.15). This file was then attributed with pertinent information such as the type of zone, the base flood elevation (if applicable), and whether or not the zone is a Special Flood Hazard Area. Additionally, a polyline version of this file was created. The *Polygons to polylines* command of the ArcView extension, CRWR Vector was used to create the file named *flood_hazard_line.shp*.

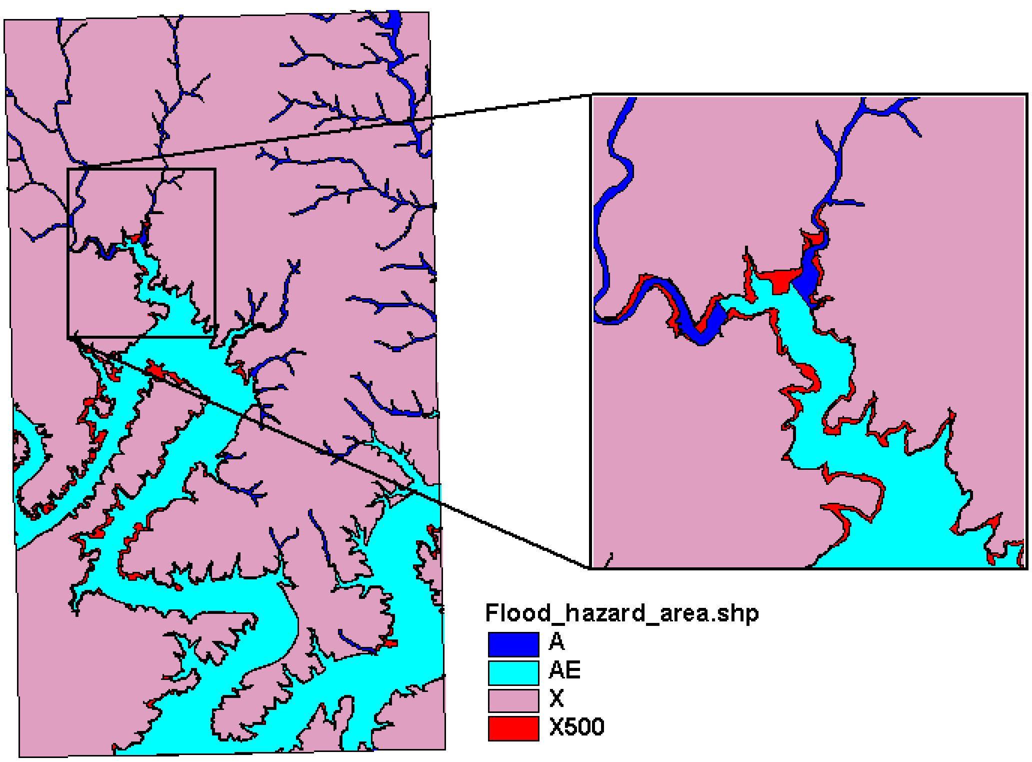


Figure 4.15 Flood Hazard Areas depicting Zones A, AE, X and X500

4.5.4 Datum Adjustment

Although not utilized for the FEMA pilot study, a procedure was developed that converts contour data to a different datum. As discussed earlier, the available contour data was referenced to the North American Vertical Datum of 1988 (NAVD 88), while the FEMA study that developed the flood elevations is based upon the National Geodetic Vertical Datum of 1929 (NGVD 29). The elevation difference between the two datums varies between two and three inches over the study area, therefore the elevation data cannot be adjusted by simply adding a constant value to the entire data set. Similarly, the 100- and 500-year water surface elevations, 716 and 728.5, cannot be adjusted to one equivalent NAVD88 elevation for the entire study area. In order to determine the correct floodplain, the NAVD88 based contours needed to be converted to NGVD 29.

First, a TIN was created using the spot elevations and the contour data available from the LCRA as mass points and breaklines using the procedure described in Section 4.5.2. Using ArcView, the TIN was then converted to a grid with a cell size of 2 feet. Because of the long processing time and large memory requirements involved in this process, the study area was broken up into 16 smaller portions.

The program, Corpscon Version 5.11.08, developed by the U.S. Army Corps of Engineers (refer to U.S. Army Topographic Engineering Center's website, http://crunch.tec.army.mil/software/corpscon/corpscon.html, for more information regarding Corpscon), was used to determine the difference in elevation between the NGVD 29 and NAVD 88 geoids at key points. The latitude, longitude, and elevation of each point were entered into Corpscon, which then generates the elevation difference. An elevation of zero feet was entered so that the returned elevation was the difference between the datums. Sample input and output data for Corpscon are shown in Figures 4.16 and 4.17.

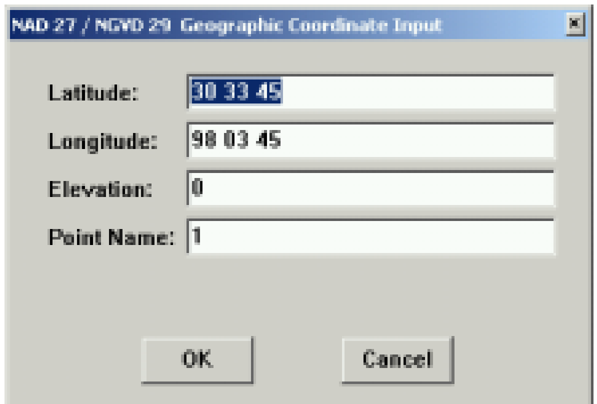


Figure 4.16 Corpscon Data Input Window

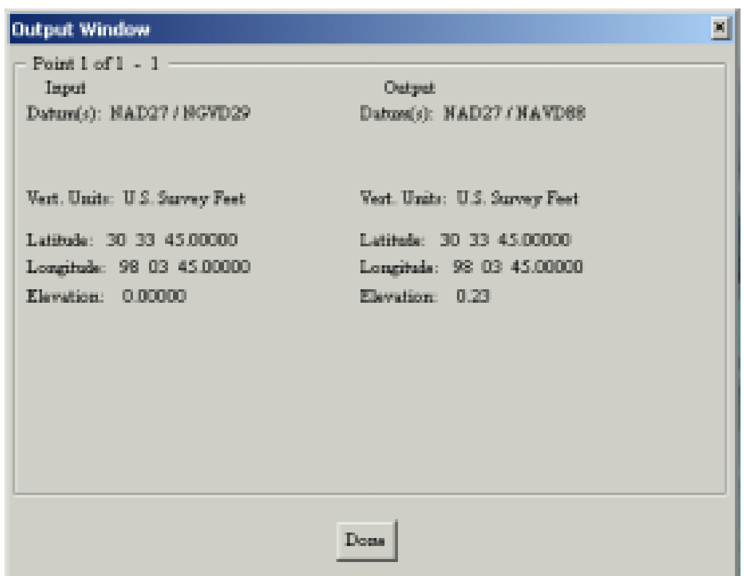


Figure 4.17 Corpscon Data Output Window

A point shapefile was then created containing a feature at each of the coordinates entered into Corpscon. This point file was then attributed to contain the calculated elevation difference at each point in a field called "datum_adj." In order to interpolate between the calculated points, a TIN was created based upon the "datum_adj" field. The point file and TIN are shown in Figure 4.18. The TIN was then converted to a grid with a cell size of 2 feet.

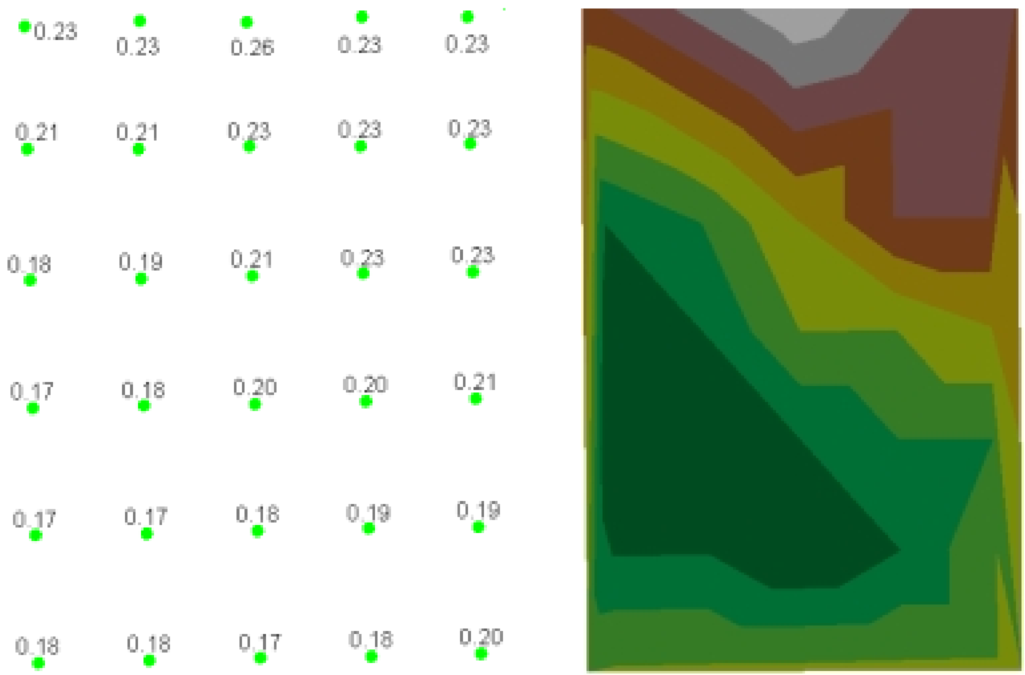


Figure 4.18 Point file and TIN showing the elevation difference between datums.

The datum adjustment grid and the grid based upon the contours can now be added together to produce a new adjusted contour grid. The grids were added using the Map Calculator function of the ArcView extension Spatial Analyst. This new grid, *adjstd_grd*, was then converted to a point shapefile using the *Gridpoint* function in ArcInfo 7.2. *Gridpoint* creates a point in the center of each grid cell and an attribute named "Gridcode" populated with the cell's value. These points are then used as mass points to create a TIN. The TIN can then be used to developed new contours based upon the vertical datum, NGVD 29 as described in Section 4.5.2 of this report.

4.5.5 Zone A Investigation

After developing the hydrographic features and flood hazard areas, there were some instances where a stream's floodplain did not contain the stream. One example of this is shown in Figure 4.19. In each case, this problem occurred in a Zone A Flood Hazard Area, where the floodplain study was not detailed. In order to see the effect that a less detailed type of study may have on the accuracy of the floodplain, a floodplain investigation was conducted on a small study area.

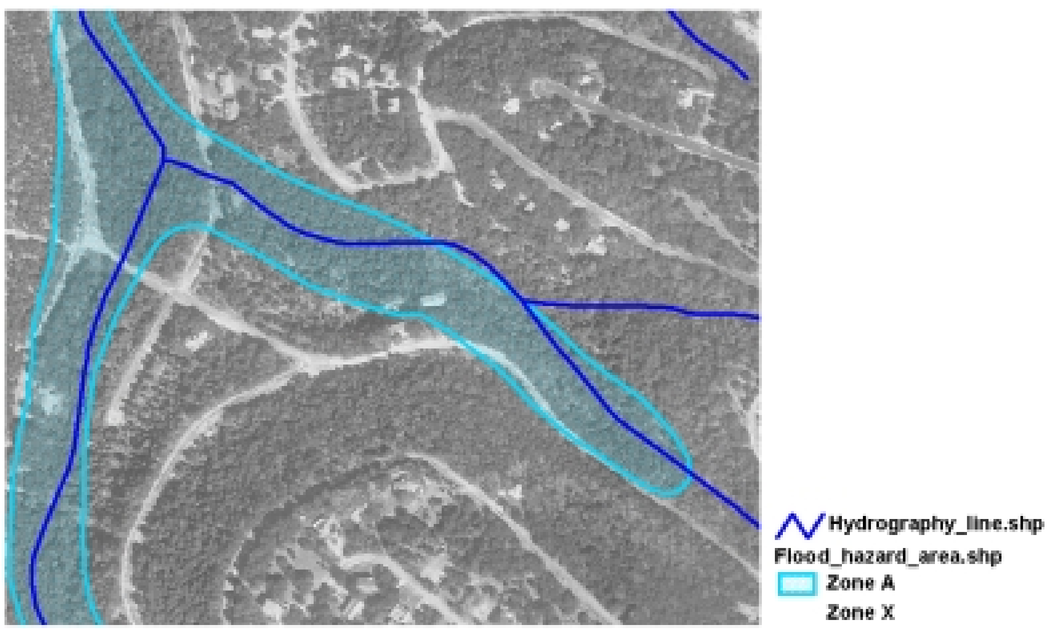


Figure 4.19 Stream outside of its floodplain

A combination of the contour data discussed earlier and a 30-meter Digital Elevation Model (DEM) was used to create a TIN of the chosen study area. The DEM was used to supply information outside the coverage of the contour data. GeoRAS was then used to extract HEC-RAS geometry data from this TIN. The basic procedure involved in using GeoRAS is to first create line shapefiles representing the stream centerline, stream banks, left and right flowpaths, and cross section locations. These shapefiles are used in conjunction with the TIN to generate 3-Dimensional shapefiles. Figure 4.20 shows the information need by GeoRAS to generate HEC-RAS geometry data.

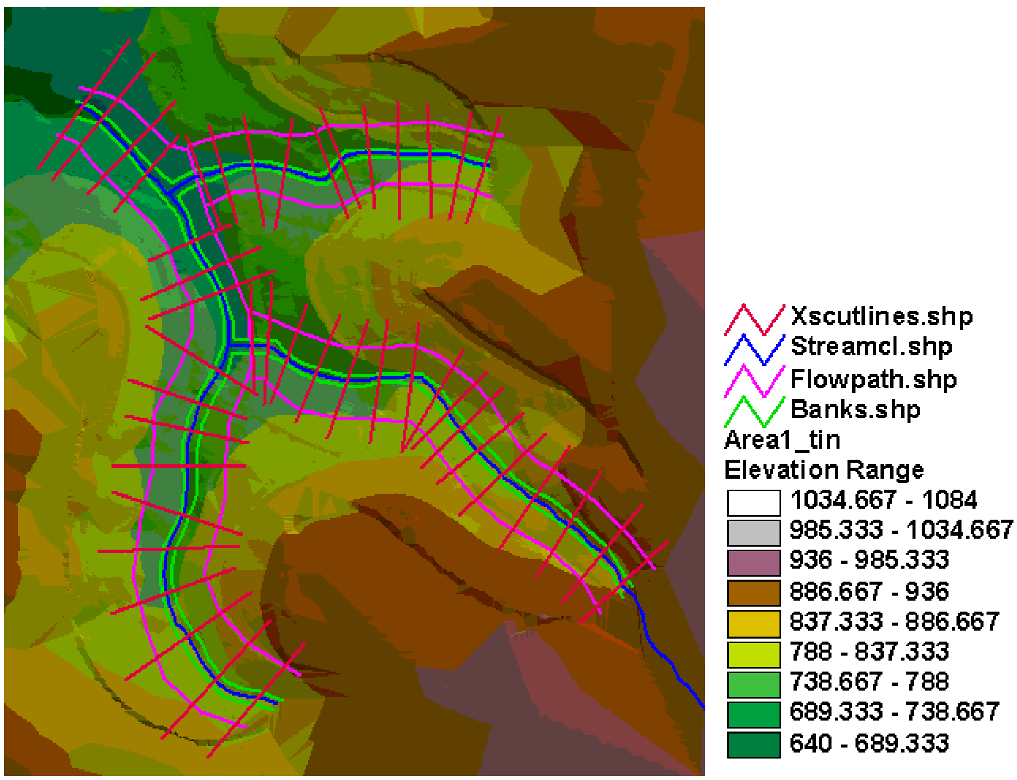


Figure 4.20 GeoRAS Input Data

Information from these shapefiles is then used to generate HEC-RAS geometry data. The next step was to define steady flow data for the RAS model. The tributaries being studied have a very small drainage area (less than 0.55-square miles). Equation 4.1, a regional regression formula developed by the USGS was used to estimate peak 100-year flows at 13 separate locations (USGS, 1993).

Equation 4.1 $Q100 = 628 * A^{0.694} * S^{0.261}$

In Equation 4.1, $Q100$ is the peak 100-year flow in cfs, A is the drainage area in square miles, and S is the average slope of the channel. The channel slope is taken as the slope between two points on the main channel, 85 and 10 percent of the channel length upstream from the point of interest. Equation 4.2 describes how the average channel slope is calculated. Z_m and L_m are the elevation and channel measure at a point m-percent of the channel length upstream of the point of interest.

Equation 4.2 $S = \frac{(Z_{0.85} - Z_{0.15})}{(L_{0.85} - L_{0.15})}$

The Rational Method was also used to determine the 100-year peak flow because of the uncertainty involved in the application of the USGS regression equations to a small drainage basin. Equation 4.3 defines the rational method, where Q is the peak discharge in cubic feet per second (cfs), i is the rainfall intensity in inches per hour, and A is the watershed area in acres. For this calculation, i was assumed to be about 4 inches per hour, which corresponds a 3-hour, 100-year storm event for this area of Texas. C was assumed to be equal to 0.58, which corresponds to the runoff coefficient suggest by the City of Austin, Texas for a forest or woodlands area with steep slopes (avg. over 7%) and for a return period of 500 years (Chow et al., 1988). This is therefore a conservative runoff coefficient.

Equation 4.3 $Q = CiA$

The variables A and S were measured using ArcView. Drainage areas were manually delineated from the contour and DEM data used to create the TIN. The 100-year flows calculated using Equation 4.1 were then entered into HEC-RAS. Figure 4.21 displays the drainage areas used to calculate the basin characteristics and the peak flows listed in Table 4.2.

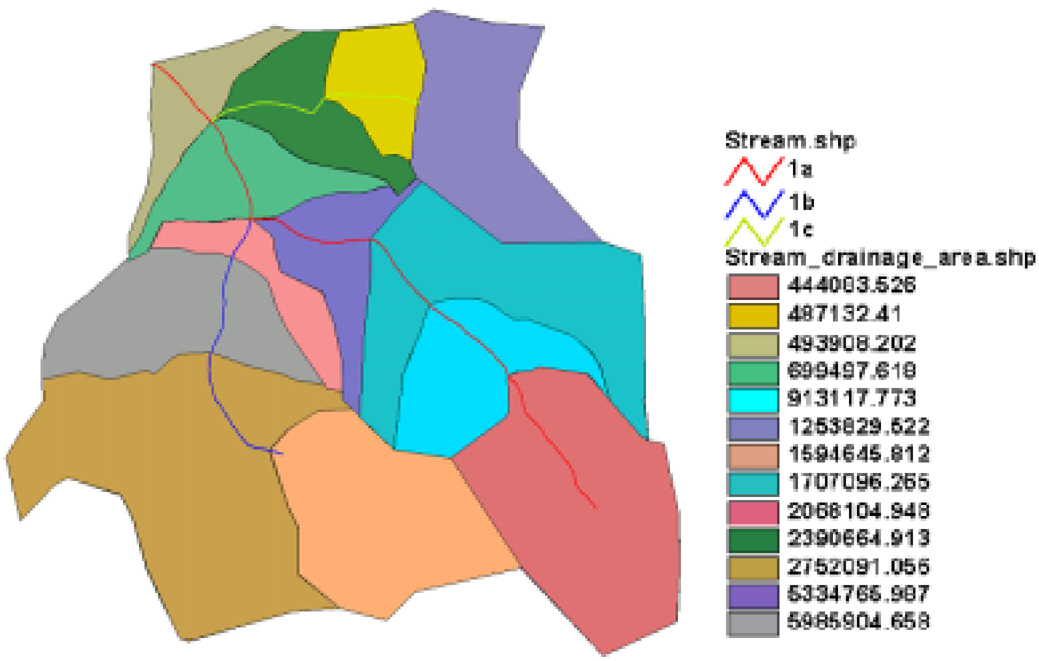


Figure 4.21 Drainage Areas

Tributary	Station (feet)	Inc. DA (sq mi)	DA (sq mi)	Length (feet)	Slope	Regression Eq. Q100 (cfs)	Rational Method Q100 (cfs)
1a	3653	0.07	0.07	2390	0.036	41.61	103.94
1a	2885	0.03	0.1	3158	0.052	58.60	148.48
1a	2246	0.06	0.16	3797	0.059	83.99	237.57
1a	1469	0.03	0.19	4574	0.059	94.64	282.11
1a	1110	0.01	0.41	4933	0.062	163.48	608.77
1a	451	0.025	0.525	5592	0.063	195.44	779.52
1a	0	0.015	0.54	6043	0.061	197.33	801.79
1b	1907	0.06	0.06	1985	0.055	41.74	89.09
1b	1006	0.1	0.16	2886	0.083	91.98	237.57
1b	133	0.03	0.19	3759	0.080	102.66	282.11
1c	1571	0.04	0.04	1711	0.107	37.53	59.39
1c	889	0.02	0.06	2393	0.109	49.93	89.09
1c	179	0.03	0.09	3103	0.092	63.36	133.63

Table 4.2 Drainage Basin Characteristics

Manning's "n" values of 0.03 and 0.04 were assigned to the channel and banks, respectively. These "n" values were taken from a hydraulic study conducted on a portion of the Colorado River just upstream of Lake Travis (Lake LBJ), with similar land characteristics. Additionally, contraction and expansion coefficients of 0.1 and 0.3, respectively, were used in the steady flow computations. A known water surface elevation of 716 was used as the downstream boundary condition, corresponding to the 100-year flood stage of Lake Travis. A steady flow analysis was then run. The results of this analysis were exported using the Export GIS Data command. GeoRAS was used to import the resulting floodplain data. GeoRAS was also used to delineate a new floodplain based upon the water surface elevations HEC-RAS calculated at each cross section and the TIN.

Figure 4.22 displays the newly delineated floodplain (shown in dark blue), the floodplain shown on the original FIRM (cyan), and buildings (red). The new floodplain is significantly smaller than the original. Two houses, highlighted in yellow, would have benefited from a more accurate Zone A delineation. The owners of these buildings would be removed from the 100-year floodplain and have their insurance premiums significantly reduced. Studies completed using the method described can be completed quickly and accurately if there is sufficient elevation data available. In this case, it would benefit the community of Lago Vista to put forth further effort in the delineation of Zone A areas.

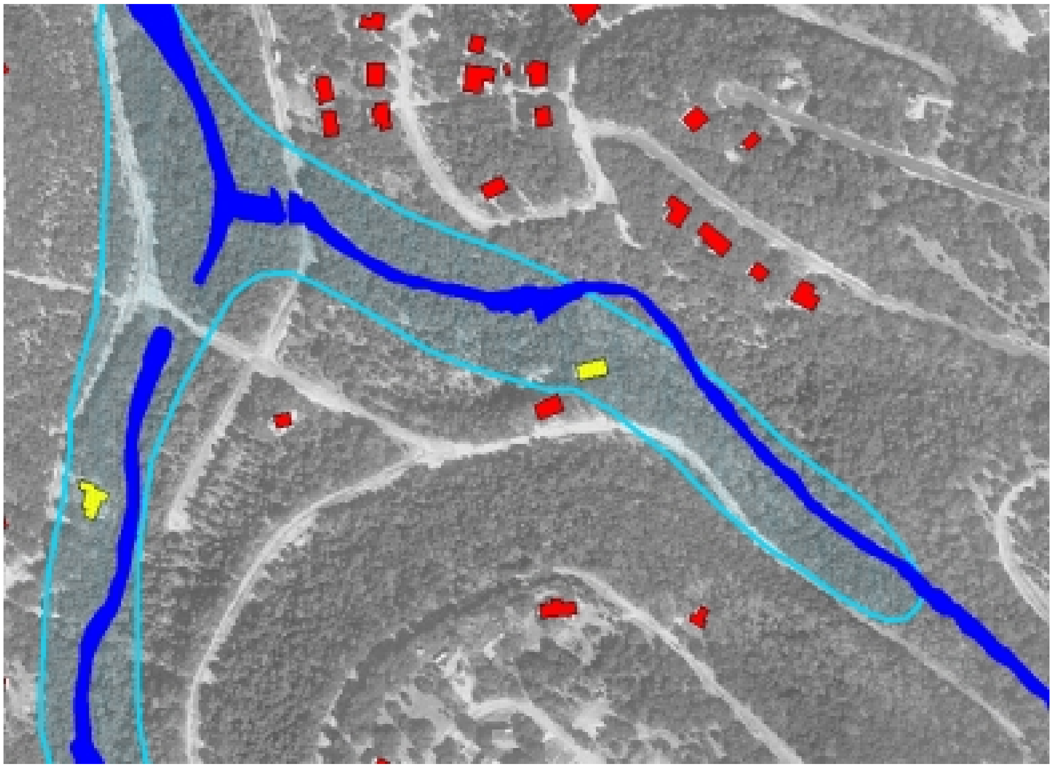


Figure 4.22 100-year Floodplain Comparison

4.6 POLITICAL BOUNDARIES

The political areas found within the Lago Vista Pilot Study include county boundaries, city limits, and extraterritorial jurisdictional boundaries. Both polygon and polyline shapefiles were created depicting the political boundaries. The shapefiles contain the same geospatial information, but contain different attributes (see UML diagram in Appendix B for more information on attributes).

The Texas Department of Transportation (TXDOT) created the Travis County boundary. The cities of Lago Vista, Lakeway, and Jonestown are located within the area studied. The city manager of Lago Vista manually drew the city limits and extraterritorial jurisdictional boundaries onto a printout of the aerial photos. This drawing was then digitized and the boundaries were manually adjusted on screen, with assistance from the city manager.

The city limits and extraterritorial jurisdictional boundaries of Jonestown and Lakeway were created by digitizing the boundaries of a paper map provided by the cities. The resulting shapefiles were then edited to contain attributes describing the type, name, National Flood Insurance Program community number, and source of each feature.

4.7 BENCHMARKS AND ELEVATION REFERENCE MARKS

Benchmarks and elevation reference marks were both digitized from the paper FIRM panels using AutoCAD. First, a digitizing board was calibrated to match the Q3 flood data to the paper FIRM panels. The points representing benchmarks and elevation reference marks were then digitized off the map, saved as an AutoCAD drawing, and converted to two separate shapefiles. The files were attributed with different information including the point's elevation, the elevation units, and the vertical datum the elevation is based upon.

4.8 ROADS

A DFIRM that uses a raster base map does not require road centerlines or outlines, only the road names as labels for display on the map panel. However, the file, *transportation.shp,* was submitted to FEMA in conjunction with an ArcView project file (.apr). When the vector shapefile and the ArcView project file are used together, the shapefile has text graphics attached to it. Alone, this file displays a centerline file created by the Capital Area Planning Council (CAPCO).

The CAPCO roads were captured from high-resolution imagery. They were digitized from the imagery and recorded in CAD format. The road coverage represents the features extracted from the CAD file for each county. This file contains many attributes including the road's name and type (road, street, lane, drive, cove, etc.) and was used as a main data source when labeling the DFIRM panels. Additionally, the MAPSCO Street Guide and Directory (MAPSCO, 1997) was used as an information source during the labeling of DFIRM panels.

4.9 UNALTERED DATA

Several data themes were used in the Lago Vista Pilot Study with minimal alterations to the original data sources. These include shapefiles of parcels, docks, buildings, contours, and spot elevations developed by the LCRA. The LCRA only developed these features within a certain distance of the Colorado River’s floodplain. Parcel outlines were created by the LCRA. Each parcel was digitized off a Travis County Appraisal District tax map. Docks and buildings were created by digitizing their outlines from digital orthophotos. Figure 4.23 displays a sample area containing parcels, buildings, and docks. A specialized contractor developed the contours and spot elevations from orthorectified aerial photos and known elevation points. The only alteration made to the data discussed in this section was the addition of a unique identification number to each feature.

Figure 4.23 Parcels, Docks, and Buildings

4.10 METADATA

Metadata compliant with the Federal Geographic Data Committee's latest metadata standards (FGDC, 1998) is required to accompany all data included in the DFIRM database. FEMA would like to have both feature level and class or theme level metadata in order to accommodate data layers with features derived from several sources.

This goal can be accomplished by attributing individual features with identification information as to their source. The metadata for each source is then stored at the level of the data layer, rather than the feature. Feature level metadata will support future map updates by allowing for data produced from particular sources to be queried and edited. Metadata used for this study was originally created using the HTML editor, Microsoft Frontpage, to edit a template containing all of the required fields. Figure 4.24 shows the HTML version of the metadata for the parcels data.

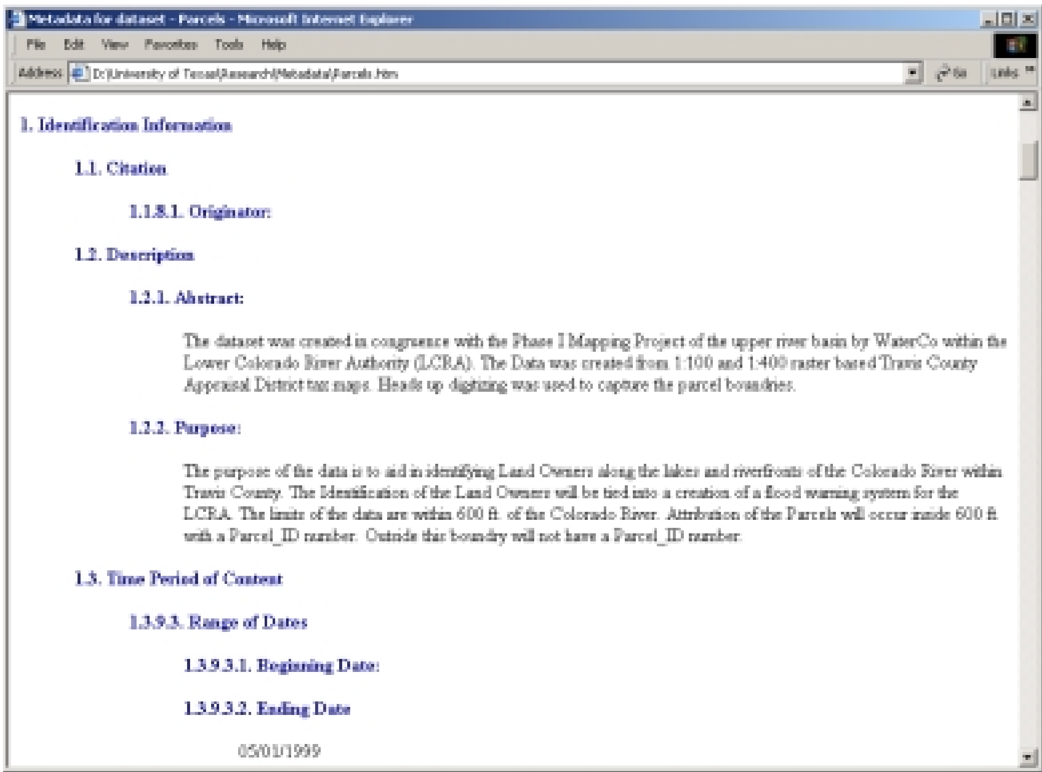


Figure 4.24 HTML Metadata for Parcels

After entering the data into a Geodatabase, the metadata feature of ArcGIS 8.1 was utilized. Metadata stored within ArcGIS 8.1 consists of two subtypes, properties and documentation. Properties, such as the extent of a shapefile or features class, are automatically derived by ArcGIS from the data source itself. Documentation consists of descriptive information supplied by the user. Metadata created by ArcCatalog is stored as XML data within the geodatabase and becomes part of the data source itself. Metadata is automatically moved, copied, and deleted along with the data source. By default, ArcCatalog will create some metadata automatically if it does not already exist.

As discussed earlier, metadata for DFIRM features are required to meet FGDC Content Standard for Digital Geospatial Metadata. This is easily accomplished using the FGDC metadata editor in ArcCatalog by clicking the data source in the Catalog tree and then clicking the "Metadata" tab. In order to use the FGDC metadata editor, the "Stylesheet" must be changed to FGDC. Metadata can then be entered by selecting the edit metadata button, , and filling in all of the required fields. Figure 4.25 shows the FGDC Metadata Editor found in ArcCatalog.

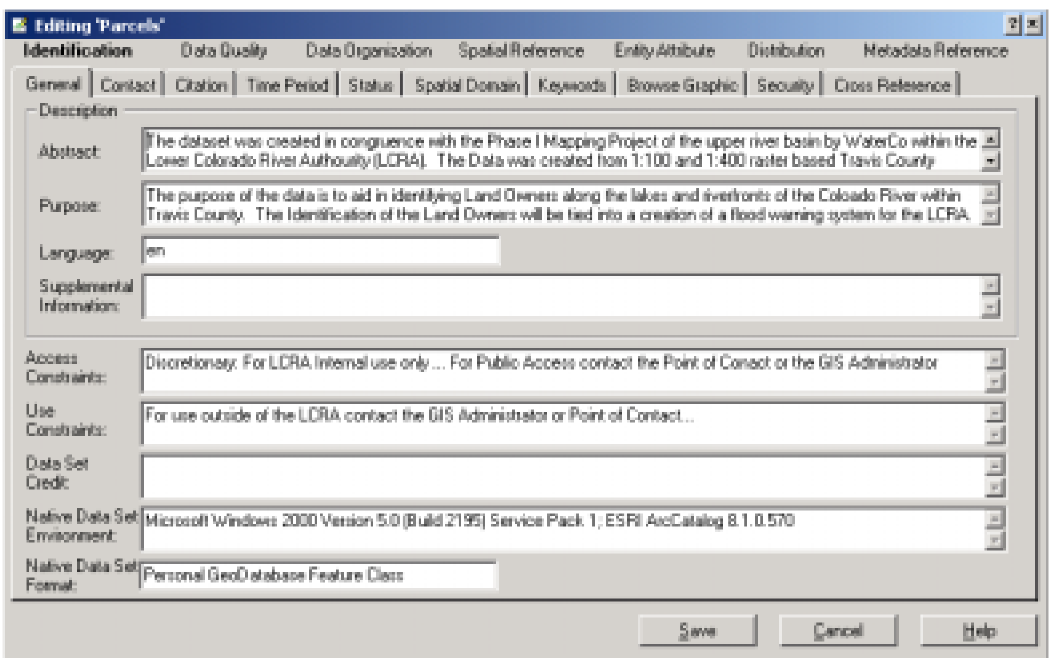


Figure 4.25 ArcCatalog's FGDC Metadata Editor

4.11 UML CREATION

Most of the information contained in a DFIRM database is used for display on a flood map or is an inventory of relevant data. The ArcGIS Hydro Data Model, discussed further in Section 5.6, can be extended so that a DFIRM, or any other dataset can be loaded in a standardized way. In order to expand the ArcGIS Hydro Data Model, the Unified Modeling Language (UML) diagram, which defines the relationships, classes, and attributes of the model, must be edited. The following process was used to create the ArcGIS Hydro Data Model with DFIRM Features Extension.

The first step in developing a database is to identify feature classes that will be imported into the data model and the desired attribute fields for each feature. FEMA has developed a set of standard DFIRM features and a corresponding set of standard attributes for each feature. All of the features listed in the FEMA document, “Standard DFIRM Spatial Database Table / Field Documentation" (FEMA, 2000), and five additional features (Buildings, Docks, Parcels, Contours, and Spot Elevations), were included in the UML diagram. It should be noted that not all of the features listed as possible DFIRM features were contained within the Lago Vista study area.

The features were then grouped into five related categories. The following is a list of the data layers that were included in the DFIRM UML diagram. Figure 4.26 is an analysis diagram displaying the five categories, the data layers within these categories and the attributes of each of the data layers. Analysis diagrams are discussed further in Section 5.6 and contained in Appendix D.

Reference Information

- DOQ Index

- FIRM Panel Areas
- Horizontal Reference Lines
- Horizontal Reference Points
- Quad Areas
- Study Info

Flood Data Features

- BFE (Base Flood Elevation) Lines
- CBRS (Coastal Barrier Resources System) Areas
- Coastal Transect Lines
- Flood Hazard Areas
- Flood Hazard Lines
- General Structures (bridges, dams, weirs, etc.)
- Hydrography Areas
- Hydrography Lines
- Levees

Political and Transportation Features

- Political Areas
- Political Lines
- Transportation (roads, train tracks, and airports)

Property Features

- Buildings
- Docks
- Parcels

Survey and Elevation Features

- Contours
- ERM (Elevation Reference Mark) Points
- Permanent Benchmark Points
- PLSS (Public Land Survey System) Areas
- PLSS (Public Land Survey System) Lines
- Spot Elevations
- Cross Section Lines

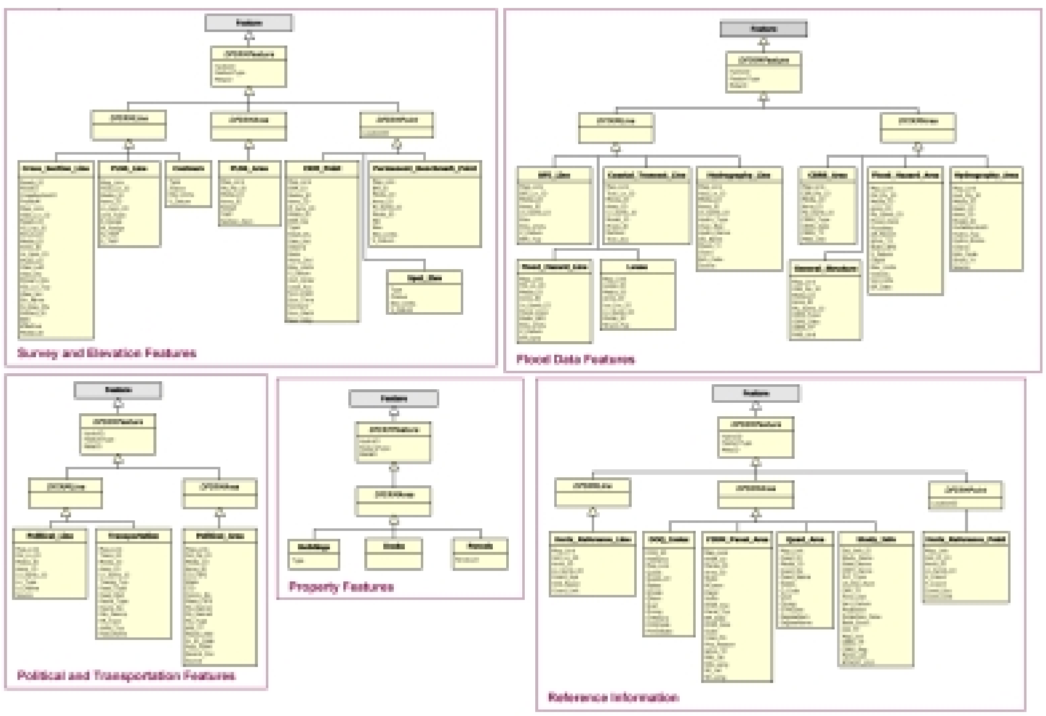


Figure 4.26 DFIRM Analysis Diagram

In order to add an extension to the ArcGIS Hydro Data Model, a new Feature Dataset was created using Visio 2000. The UML diagram for the ArcGIS Hydro Data Model was opened in Visio and a new package was added to the model. The package was then renamed "DFIRM Features" and its stereotype was set to FeatureDataset (see Figure 4.27). New static structure diagrams for each of the groups listed above (Reference Information, Flood Data Features, etc.) were then created within the *DFIRM Features* package. This provides a worksheet to which new feature classes can be added.

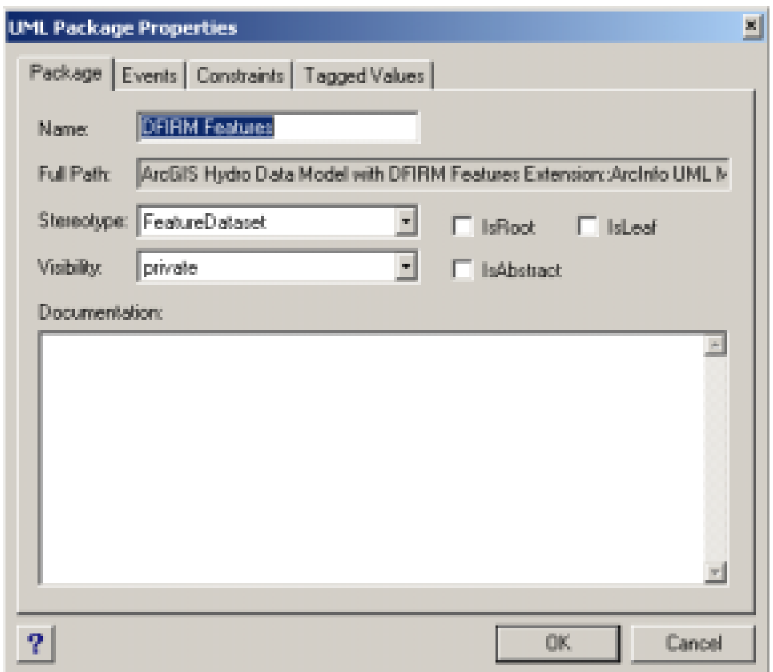


Figure 4.27 Creating a New Feature Dataset

Feature classes of each of the items listed above were then created in their corresponding static structure diagrams. A generic class is added by dragging it into the structure diagram. The class can then be modified by editing its properties and defining attributes. Figure 4.28 is a completed feature class describing the USGS Quad index and its attributes. The field type (integer, string, date, etc.) of each attribute is also described.

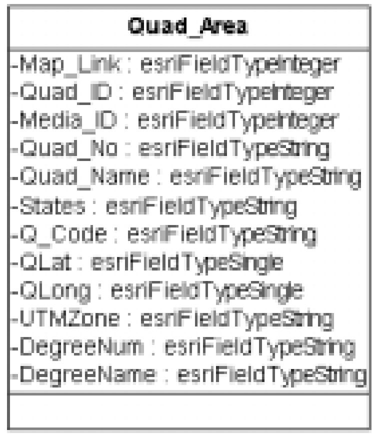


Figure 4.28 UML Feature Class

Each of the diagrams begins with an abstract class called *DFIRMFeature* that was created to provide the attributes "HydroID" and "Meta_ID" to each of the other classes. An abstract class contains no features, but can be used to group other classes together and pass along its attributes.

The abstract classes *DFIRMPoint*, *DFIRMLine*, and *DFIRMArea* were created as a child of the abstract class, *DFIRMFeature*, in order to pass along the "GeometryType" tagged values of "esriGeometryPoint", "esriGeometryPolyline", and "esriGeometryPolygon", respectively. A generalization relationship was used to create the inheritance between the new DFIRM feature classes and either, *DFIRMPoint*, *DFIRMLine*, or *DFIRMArea*, depending on the spatial representation of the data. The "GeometryType" tagged value allows the DFIRM feature classes to be geometry specific (see Figure 4.29).

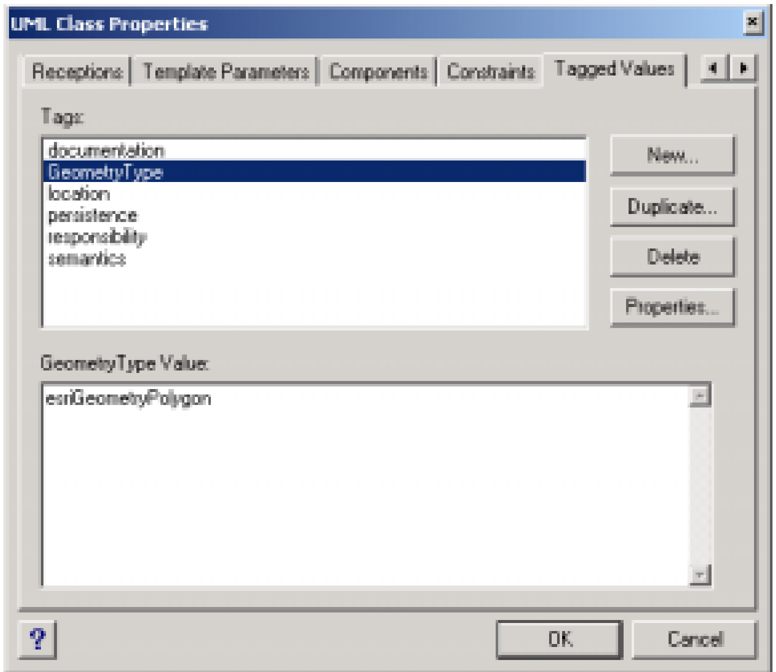


Figure 4.29 GeometryType Tagged Value

By clicking on the attribute tab found of the UML Class Properties window, attributes specific to each individual class can be added. The field type of the attribute is also specified at this time. Field types define what type of values can be entered into the attribute table of a class, such as Integer, String, or Boolean. All attributes and attribute field types were based upon the FEMA document, *Standard DFIRM Spatial Database Table/Field Documentation*, existing attributes of the data itself, or the ArcGIS Hydro Data Model. Figure 4.30 displays the window used to enter and edit attribute information.

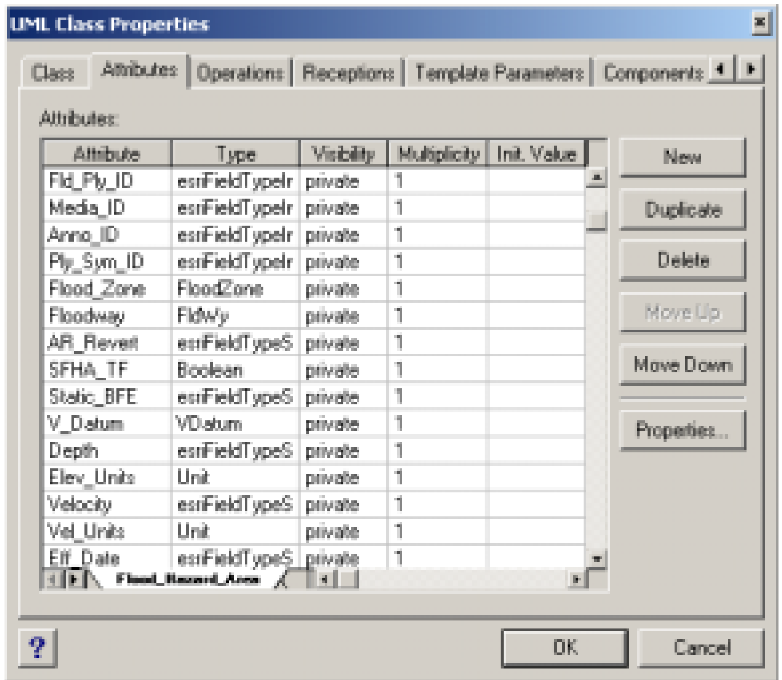


Figure 4.30 Editing Attributes for Flood Hazard Areas Feature Class

Many of the feature classes in the DFIRM database use coded value domains to describe attributes of the data. A coded value domain is a way of constraining the values allowed in any particular attribute. A coded value domain can apply to any type of attribute; text, numeric, date, etc. In this case, integers were used to represent text descriptions of the attribute. For example, many of the features in the DFIRM database have the attribute field “Vdatum”. This is used to describe the vertical datum for which an elevation measurement is based upon. A coded value domain was created to limit the values that can be entered into the “Vdatum” attribute field to NGVD29, NAVD88, MSL, and Other. In this case the value “1” is used to represent NGVD29. The coded value domain includes both the actual value that is stored in the database and a more user-friendly description of what that value actually means.

Coded value domains were formed by creating a new class and setting its stereotype to "CodedValueDomain." The coded values were entered in as attributes of the coded value domain. The first three attributes shown in Figure 4.31 are standard attributes required for the model. The following four attributes are the coded value domains. Therefore, if a contour line feature has a value of three describing its vertical datum, ArcGIS will automatically display "MSL" (Mean Sea Level) in the attribute table.

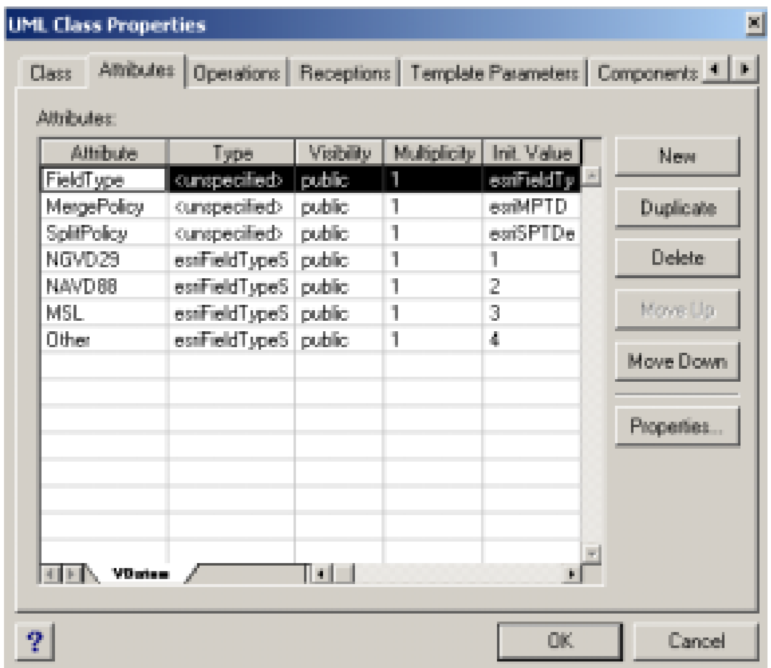


Figure 4.31 Defining a Coded Value Domain for Vertical Datum

4.12 GEODATABASE AND MAP TEMPLATE

The new UML diagram created for the ArcGIS Hydro Data Model with DFIRM Features Extension was then exported to a Microsoft Repository using Visio 2000's *Export* command found under the UML menu. A Microsoft Repository supports the storage of information related to the development of software, including object models created using UML. The framework of the entire model is now contained within the Repository.

The schema creation wizard was then used to convert the Repository into a tabular structure, or schema, for loading data into a geodatabase. A table is created for each UML class defined in the model, and a field is created in that table for each UML attribute. In this case, the data was already developed as shapefiles. These shapefiles can be imported into a geodatabase using ArcToolbox or ArcCatalog. The schema creation wizard can take a Repository, create schema, and then apply the schema to the existing geodatabase.

The schema creation wizard is accessed by adding a button to the ArcCatalog interface. The *Customize* command found under the Tools menu allows the user to add toolbars or commands to the interface. Selecting the Commands tab, then the *Add from file* button, browsing to the Bin directory where ArcGIS was installed, and selecting *SchemaWiz.dll* adds the schema wizard icon to the right side of the Commands window (Figure 4.32). The icon can then be dragged onto a toolbar.

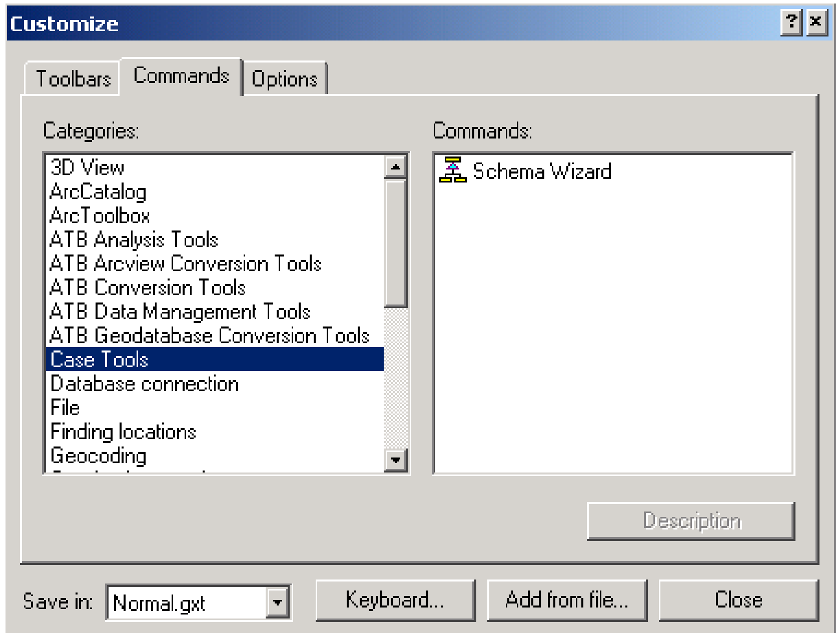


Figure 4.32 Adding the Schema Creation Wizard

Clicking the schema wizard icon and selecting the Repository brings the user to a tree-view of the schema. Using this view, the object classes and feature datasets that apply to the model can be selected. Those feature datasets that do not apply to the DFIRM database are unselected. When applying a schema to an existing geodatabase, the schema creation wizard will search for objects already within the geodatabase that have the same name as objects in the model. These objects will be shown with a red shadow in the tree-view (see Figure 4.33).

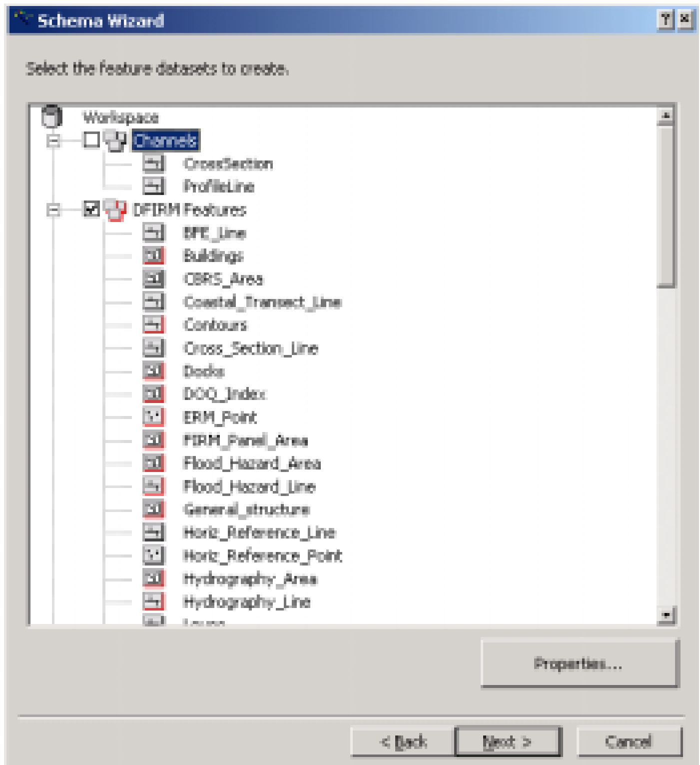


Figure 4.33 Selecting the Feature Datasets to Create

Additionally, existing classes can be paired up with model classes having a different name by selecting the class, clicking the *Properties* button, and then clicking the Exists tab. This is also the screen where attributes of existing data and those found in the Repository can be matched up. Any attribute fields that have "click to select…" listed in the "In existing object" column, as shown in Figure 4.34, must be changed to either match an existing attribute field or classified as "Add Field" before the schema can be fully applied.

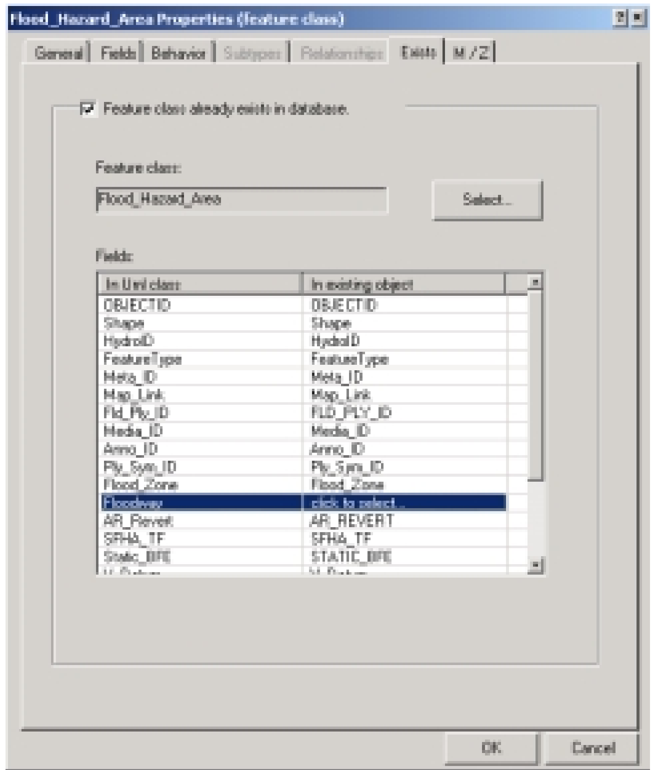


Figure 4.34 Matching existing and UML class attributes

Once the schema was applied to the geodatabase, a DFIRM map panel was created using ArcMap. The feature datasets contained within the DFIRM geodatabase were selected, adding all of the data except the base map images, which must be added separately. The current version of ArcGIS does not allow raster data to be included in a geodatabase. Each data layer's color, line weight, and fill type is then edited to meet the DFIRM production standards described in "DFIRM Graphic Specifications" (FEMA, 2000).

Standard symbols for each layer are created and saved in ArcMap as a Style to ensure fast and accurate replication. Creating a layout displays the data at the correct scale and enables the DFIRM standard border and legend information to be added as shown in Figure 4.35. Once the first DFIRM layout has been completed, a map template was created by saving the layout as an ArcMap Template. The map template allows the production standards of the DFIRM panel to remain consistent when applied to additional panels. Additional map panels are produced by simply opening the template and setting the data sources of each map feature to the appropriate feature class.

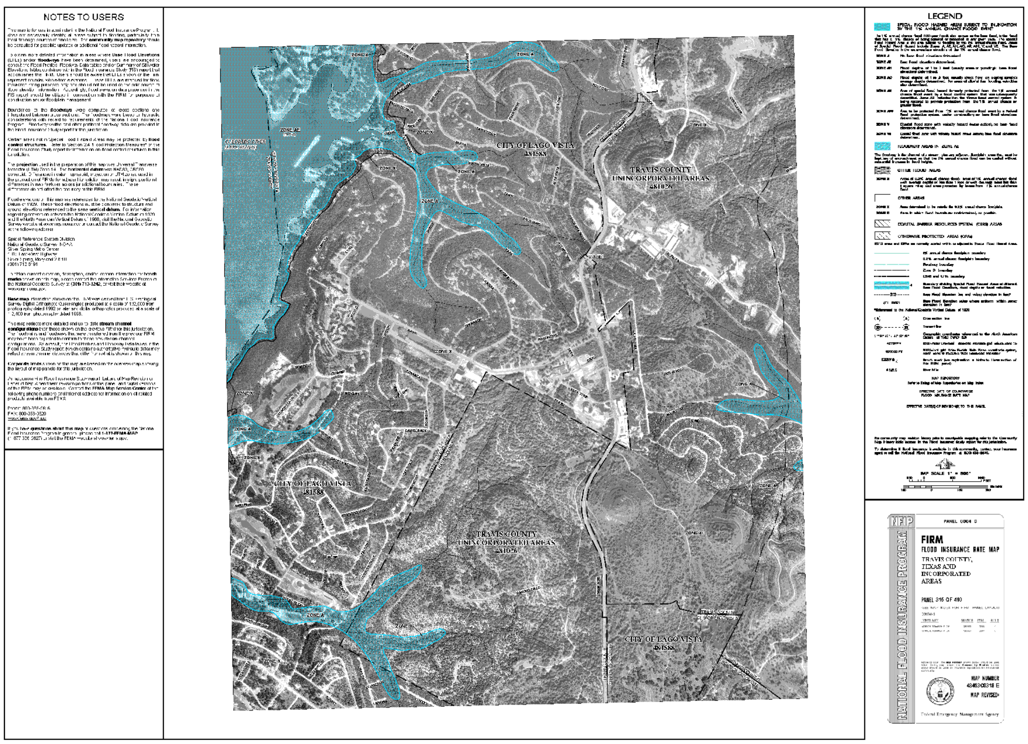


Figure 4.35 DFIRM Produced Using ArcMap

Chapter 5: Results

5.1 MILESTONE 1

After the development of a work plan and production schedule, the relevant DFIRM specifications and guidelines were reviewed. The results of this literature review were discussed in detail in Chapter 2 and briefly in Section 4.1 of this report. The Flood Insurance Study for Travis County (FEMA, 2000) was then examined to determine the water surface elevations of the 100- and 500-year events for Lake Travis. It was found that the Base Flood Elevation (100-year flood) for Lake Travis is 716 feet above mean sea level. The 500-year flood stage was found to be 728.5 feet above mean sea level. At this stage, the lake rises 14.5 feet above the spillway elevation.

A collection of the standards and documents in effect for this study was prepared and distributed to all of the parties involved. Following the direction of these standards, it was decided to replace the six 1" = 800' scale original FIRMs with seventeen maps produced at 1" = 500' and two maps at 1" = 1000'. The two new maps produced at a less detailed scale describe an area with very few houses, roads, and flood hazards.

At this point, the panels were numbered one to nineteen, from left to right, and top to bottom. Appendix A contains the proposed DFIRM panel layout, and a description of the features that would be included on the proposed base map panels, as it was understood at the time. Figure 5.1, shown below, shows the proposed panel layout, city limits, and Lake Travis. Both the panel layout and map scales were accepted by FEMA's Mapping Coordinator Contractor.

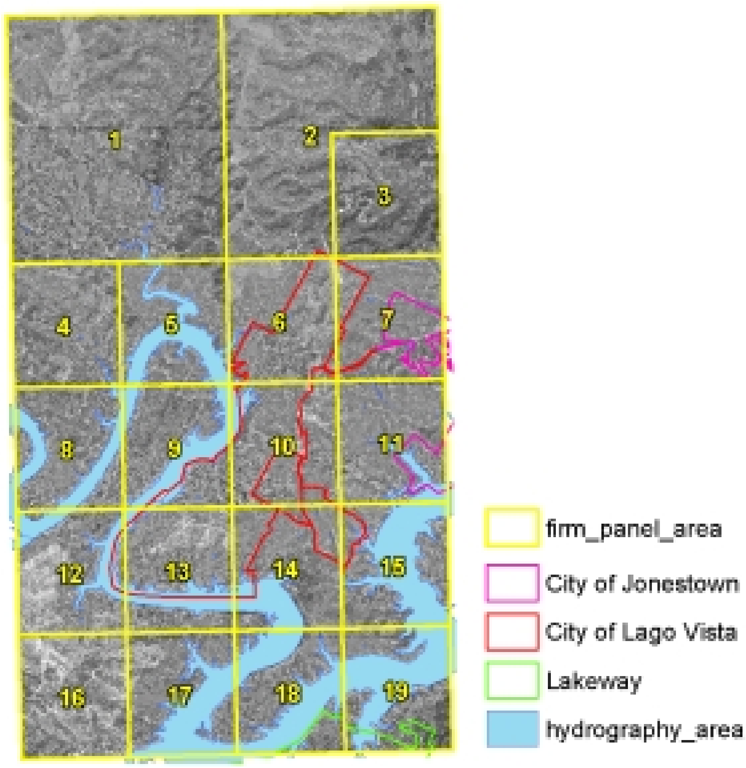


Figure 5.1 DFIRM Pilot Study Panel Layout

One of the base map images, created by combining a DOQ and the LCRA's digital orthophotos as described in Section 4.3, was then sent to FEMA's Mapping Coordination Contractor for review. The base map was found acceptable and the remaining panels were created following the same methodology. Examples of the initial data, used to develop the other DFIRM features, were also sent to the Mapping Coordination Contractor for review. As a result of this review, it was made clear that the metadata of all the files needed to be improved, and some of the files' attributes needed to be further developed.

Additionally, the road centerline and political boundary files that were submitted were determined to be unsuitable for use on FIRMs. The original road centerlines submitted for review were developed by the Texas Department of Transportation (TXDOT) and only met National Map Accuracy Standards for 1:24,000 scale products. This file was replaced with the Capitol Area Planning Council (CAPCO) road file described in Section 3.6. When a raster base map is used, only road labels, not centerlines, are shown on the printed FIRM. Labels were created using ArcView and attached to the centerline shapefile. When the ArcView project file and the shapefile are used together, the labels are visible. Both the centerlines and their labels are shown below for a small portion of the study area.

Figure 5.2 Road Centerlines

The political boundary file, also developed by TXDOT, was found to be out of date. New representations of the city limits and extraterritorial jurisdictional (ETJ) areas had to be created with cooperation from the city managers of Lago Vista, Lakeway, and Jonestown (as described in Section 4.6). The Travis County boundary was retained from the original TXDOT file, as it was still accurate. Both polygon and linear representations of the political boundaries were created. Figure 5.3 shows the city and ETJ limits of Jonestown and Lago Vista, as well as a portion of the county line.

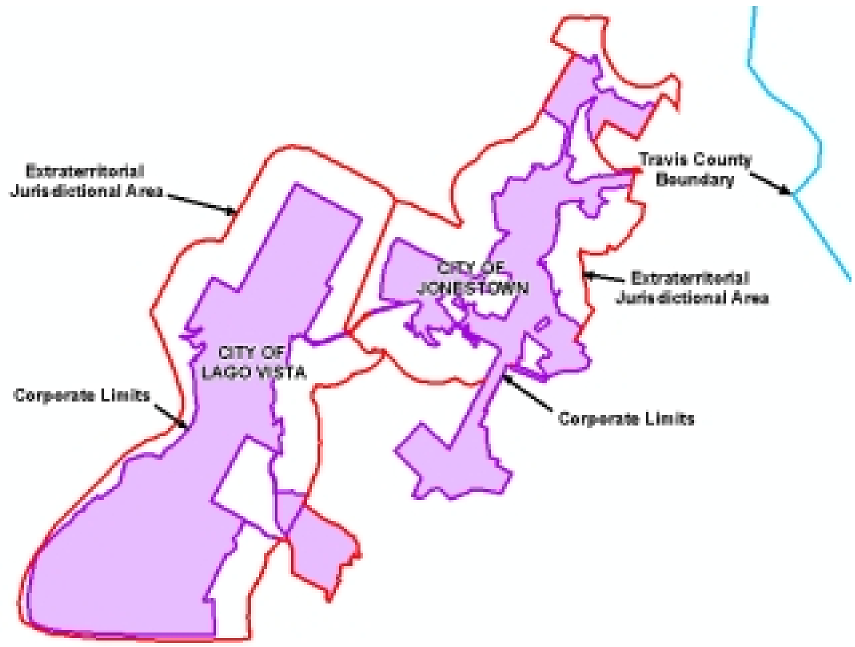


Figure 5.3 Political Features

5.2 MILESTONE 2

Milestone 2 required the development of one completed DFIRM panel, panel 10 as shown in Figure 5.1. Major tasks included: the population of attributes describing the name and NHD Reach Code of each of the hydrographic features for which data was available; development of the flood hazard areas; labeling roads within 1000 feet of a flood hazard area; working with the city manager of Lago Vista to develop the city and ETJ boundaries (Lago Vista is the only city located on panel 10); digitizing benchmarks and elevation reference marks from the paper FIRM; and updating and completing metadata for each file.

The data was then assembled into an ArcView project, and a layout displaying panel neatlines, benchmarks, ETJ areas, city limits, hydrographic features, and flood zones was created. All of the additional data described earlier was also submitted at this time, but not included in the layout. The layout, shown in Figure 5.4, was printed as designed at a scale of 1:6,000 and included with the data submission constituting Milestone 2.

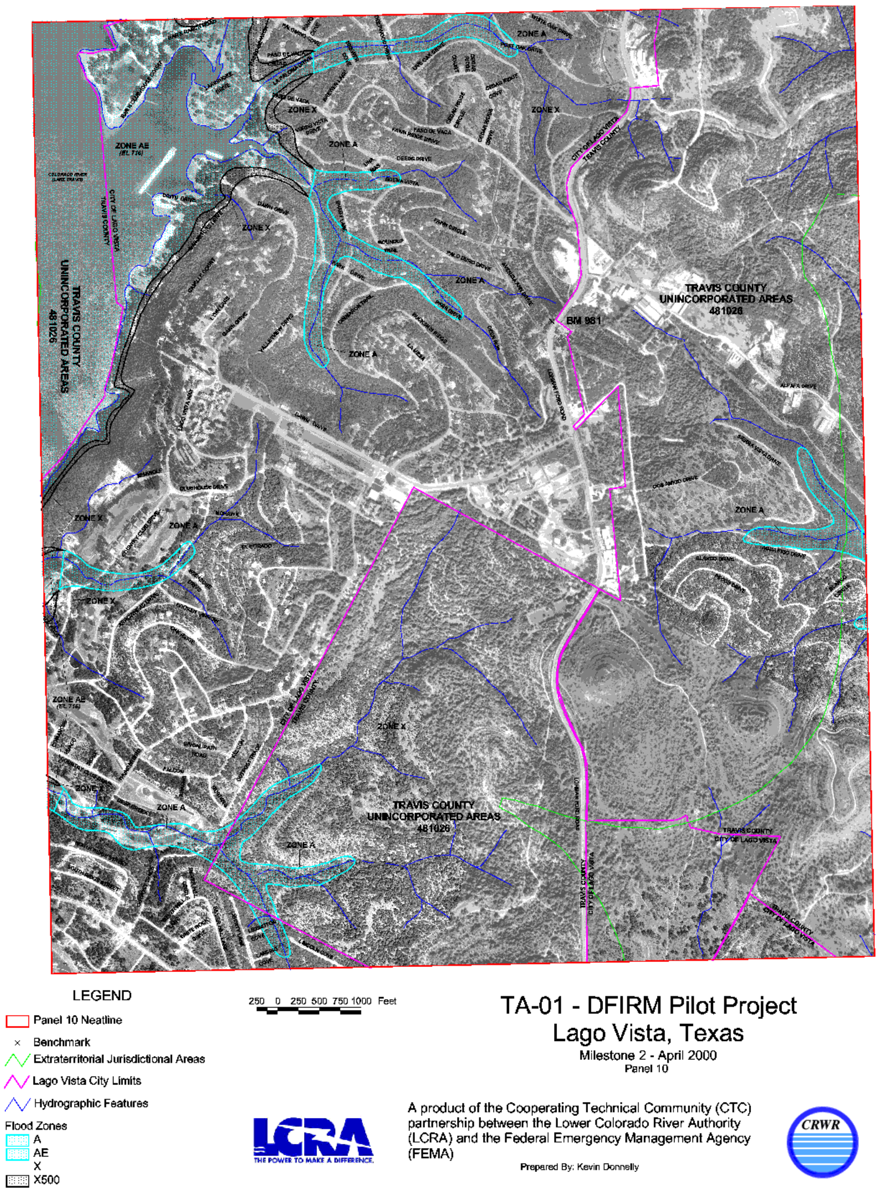


Figure 5.4 Milestone 2

5.3 MILESTONE 3

Discussions with the Mapping Coordination Contractor resulting from the Milestone 2 submission centered on the flood hazard areas. It was desired to have people that live in or out of a floodplain, as it is currently delineated, retain their original status. This was important to FEMA because this project did not involve a formal floodplain revision. It was decided to maintain the road-floodplain relationships and the building-floodplain relationships, for all Zone A areas developed from the Q3 Flood Data. The new Zones AE and X500 would continue to be created true to the contour data without concern of violating the road-floodplain relationship.

After completing delineation of the new floodplains, a comparison was made between the 100-year floodplains shown on the original FIRM and the new DFIRM. Three of the panels were not affected by the delineation of new floodplains, because they did not contain AE flood zones, only A zones. Table 5.1 compares the area inundated by the two versions of the 100-year floodplain. The percent difference is defined as the area inundated by the FIRM minus the area inundated by the DFIRM, divided by the area inundated by the FIRM.

Panel Number	Area (Acres)		Difference %
	FIRM	DFIRM	
1	518.4	524.6	-1.2
4	108.4	89.2	17.7
5	1335.0	1291.8	3.2
6	249.1	270.4	-8.6
8	866.7	828.9	4.4
9	1230.0	1162.6	5.5
10	324.7	326.4	-0.5
11	446.8	433.7	2.9
12	708.2	691.4	2.4
13	845.8	804.2	4.9
14	676.5	668	1.3
15	1412.7	1423	-0.7
16	13.8	13.5	2.2
17	1242.2	1231.8	0.8
18	1394.3	1368.9	1.8
19	1388.7	1415.8	-2.0
Total	12761.3	12544.2	1.7

Table 5.1 100-year Inundation Area Comparison

The table shows that the newly delineated DFIRM floodplain removed 217 acres from the floodplain, or 1.7% of the original area. The floodplains agree with one another in some areas and differ by over 500 feet in others. Figure 5.5 shows the original FIRM Zones A and AE as a cyan colored polygon. The newly created DFIRM Zone A is shown as purple shading, while Zone AE is shown as green shading. It can be seen that the two A zones are identical, while the AE zones differ significantly in some areas.

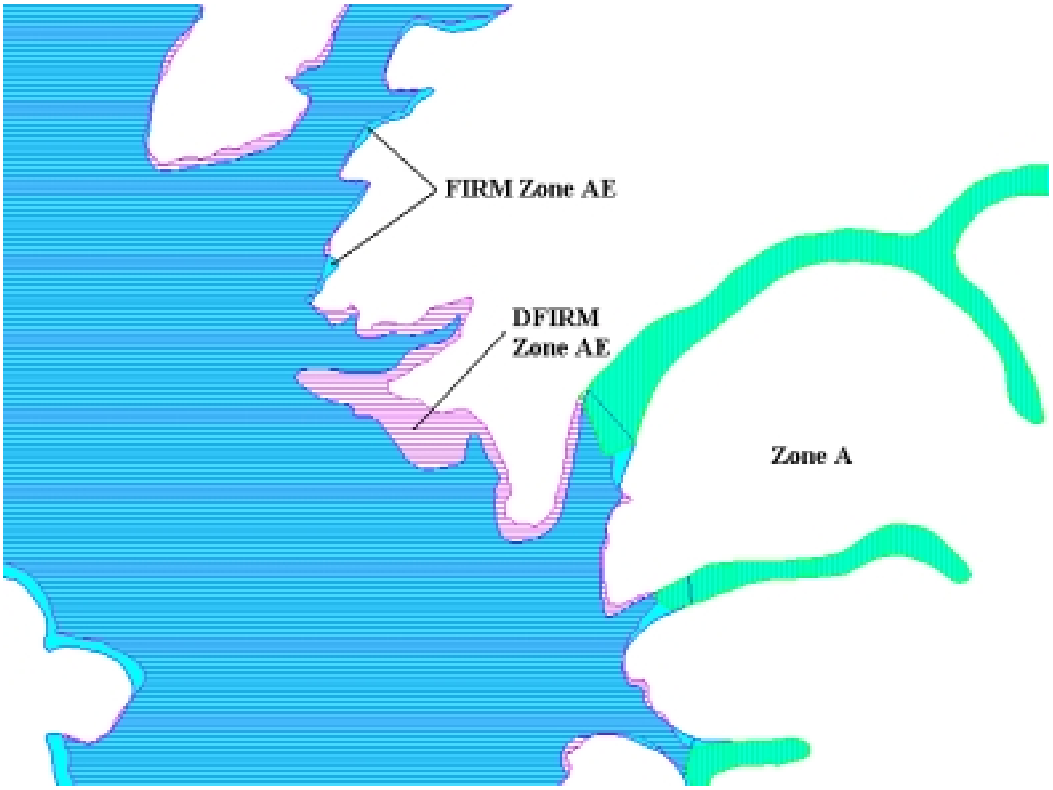


Figure 5.5 Zone AE Comparison

The geospatial analysis capabilities of GIS were used to determine how updating the floodplains affected buildings in the area. A total of 1,833 buildings were at least partly located within the original 100-year floodplain. Updating the floodplain based upon the new contour data removed 939 of these buildings and added 74 new ones. Overall, 865 less buildings are in the floodplain because of this study. Figure 5.6 shows some of the buildings that were removed from the original 100-year floodplain. These buildings are highlighted in yellow, the original floodplain is shown as a cyan colored line, and the new floodplain is shown in purple.

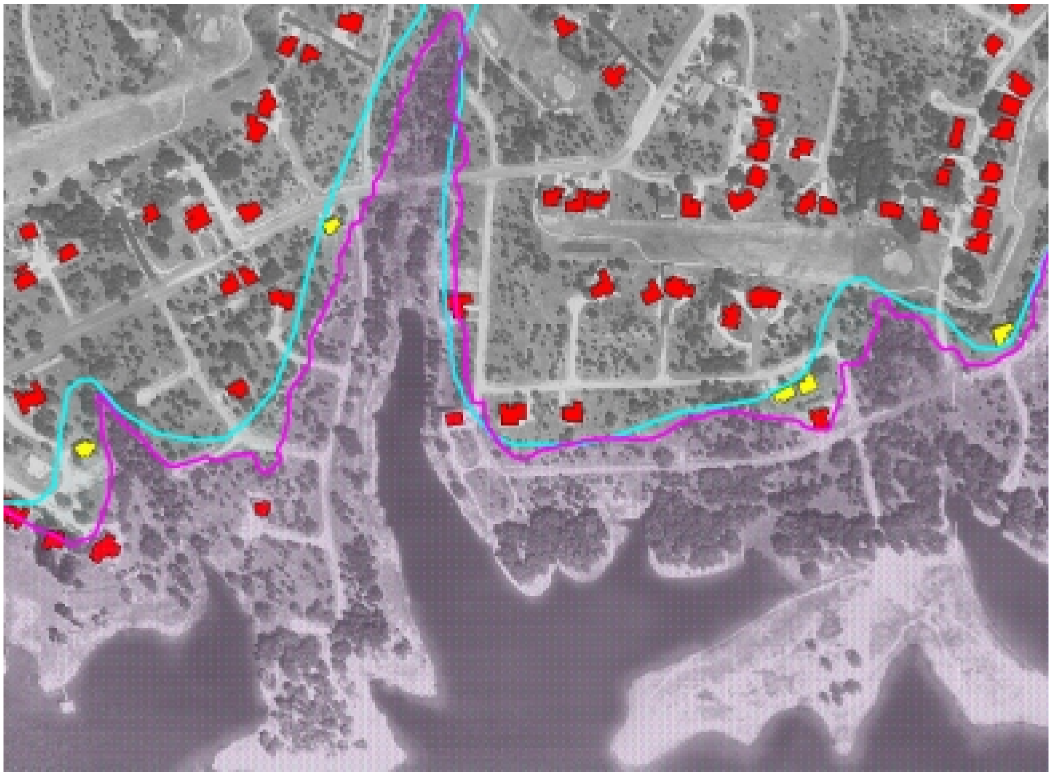


Figure 5.6 Buildings Removed from Floodplain

Another concern, raised during the evaluation of Milestone 2, was that some of the creeks go outside of their respective flood boundary. There was much discussion regarding this issue and it was decided that two versions of the creek centerlines would be produced. One displaying the creeks digitized from aerial photos and the other adjusted so that each creek remains in its floodplain. The results of the Zone A investigation described in Section 4.5.5 are described later in this chapter.

The data preparation for developing Milestone 3 consisted mainly of applying the lessons learned during Milestone 2 to all 19 panels within the study area. This involved developing the political boundaries for Lakeway and Jonestown, labeling roads, populating attribute fields, and creating the floodplains and base map images for the remaining panels.

The result was a set of digital files containing DFIRM data for all 19 panels. These files include attribute tables as described for a Standard DFIRM Spatial Database and metadata per FGDC standards. Milestone 3 also included 19 hard copy plots of each DFIRM panel showing similar features to those in Figure 5.4.

Although, FEMA's Mapping Coordination Contractor agreed to create the official legend, notes, and title block for the panels in the pilot study, these were also created by the author for display purposes. The legend and title block were scanned from DFIRM samples provided by FEMA, and the notes were manually created based upon the document *DFIRM Graphics Specifications* (FEMA, 2000). Figure 5.7 shows one of the FIRM panels that was converted to digital format. This particular panel was transformed into four separate DFIRM panels because of the change of scale. The red outline shows the area depicted in the DFIRM shown in Figure 5.8. Note that the old FIRM panels, unlike the DFIRMs, are not oriented to show north towards the top of the page. In Figure 5.7, the north arrow points toward the left side of the map.

Figure 5.7 Paper FIRM Panel

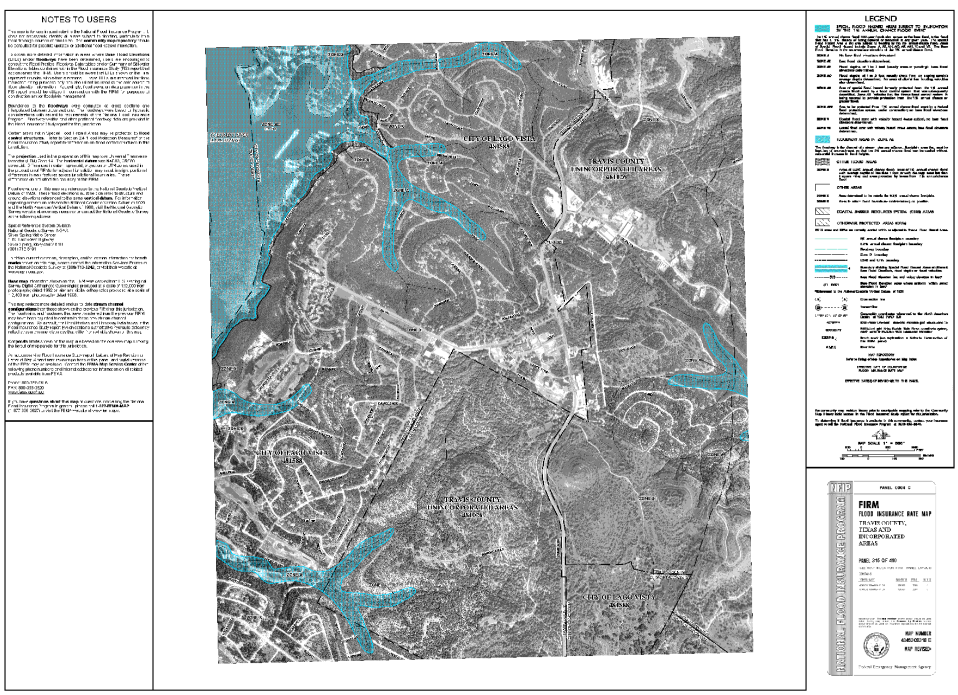


Figure 5.8 Final DFIRM Panel

5.4 DATUM ADJUSTMENT

Contour data developed based upon the North American Vertical Datum of 1988 (NAVD88) was adjusted to the National Geodetic Vertical Datum of 1929 (NGVD29). This was done so the Base Flood Elevations determined by the Travis County Flood Insurance Study and the elevation data used to delineate the floodplains would be based upon the same datum. The adjusted contour data was not included in the official DFIRM data submission to FEMA. It was decided by the Mapping Coordination Contractor that a note describing this problem would be included on the DFIRM panel.

In this area of the country, the elevation difference between the two datums varies between two to three inches. Therefore, large changes to the contours were not expected. Figure 5.9 shows a comparison between the two versions of the contour data. The red lines represent the original NAVD88 based contour, while the blue lines represent the NGVD29 based contours. Because this is a hilly area, most of the contours were shifted between 0.6 and 1.7 feet. There were some flat areas where the horizontal location of the contours differed by over 10 feet. It should be remembered that the reason for changing the datum of the contours to NGVD29 is to correctly delineate the floodplain. This is easily accomplished by applying the methodology described in Section 4.5 using the new NGVD29 based contours.

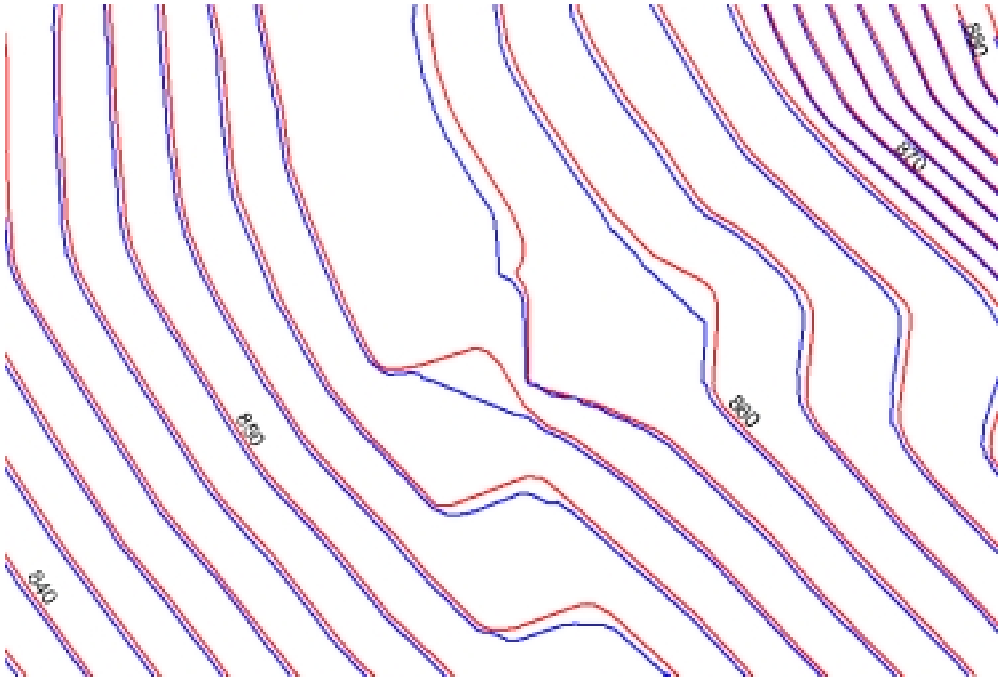


Figure 5.9 Contour data based upon NGVD29 (blue) and NAVD88 (red)

5.5 ZONE A INVESTIGATION

When a stream meanders outside of its own floodplain, it is immediately obvious that something is wrong. Either the stream location is off, or the delineation of the floodplain is incorrect. Several streams with this situation were found during this study. According to the Flood Insurance Study produced for Travis County (FEMA, 2000), the floodplains in this area were developed using 1:24,000 scale USGS Topographic Maps. The new streams were developed from more current and accurate (1:4,800 scale) data. In order to make the maps "look right," FEMA's Mapping Coordination Contractor requested that the streams be edited so that they appear to be contained within the floodplain. As a result, two hydrography files were submitted with the DFIRM Pilot Study; one edited version named *hydrography_line_display.shp* and the other *hydrography_line(accurate).shp*.

The delineation of one of these Zone A areas was replicated using approximate methods (as described in Section 4.5.5) appropriate for a Zone A delineation. The results of this analysis are presented below.

Both regional regression equations and the Rational Method were used to determine the 100-year peak flows for a selected tributary of Lake Travis. Using the USGS regional regression equations, the maximum peak flow at the confluence with Lake Travis was found to only be about 200 cfs. The Rational Method returns a value equal to about 800 cfs. Regardless of the flow value used, the validity of the existing flood zones is questionable, considering they are shown to be about 240 feet wide in this area.

Figure 5.10 shows an X-Y-Z perspective view of the water surface calculated by HEC-RAS using the Rational Method flows. The water surface elevations were then brought into GIS where a new floodplain was delineated using HEC-GeoRAS. The steady flow calculations performed by HEC-RAS are based upon the solution of the one-dimensional energy equation. Energy losses are evaluated by friction losses (using Manning's equation) and contraction / expansion losses. The methods used by HEC-RAS are more accurate than those recommended by FEMA for approximate methods of floodplain determination.

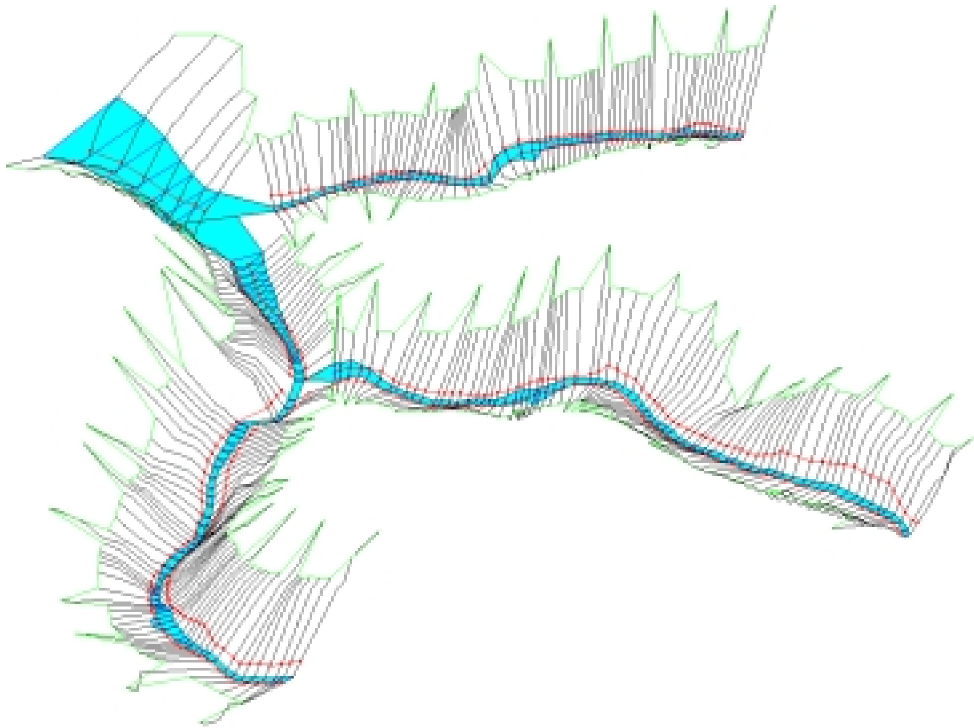


Figure 5.10 HEC-RAS 3D-perspective view of calculated water surface elevation

Figure 5.11 compares the original Zone A designation to one delineated using the steady flow values calculated from the Rational Method. A one-foot grid shows the newly delineated floodplain and the flow depth. The color of this grid ranges from white to very dark blue, where any cell shown in a color lighter than navy blue is less than four feet deep. The majority of the three streams flow at less than four feet deep, even during the 100-year flood event.

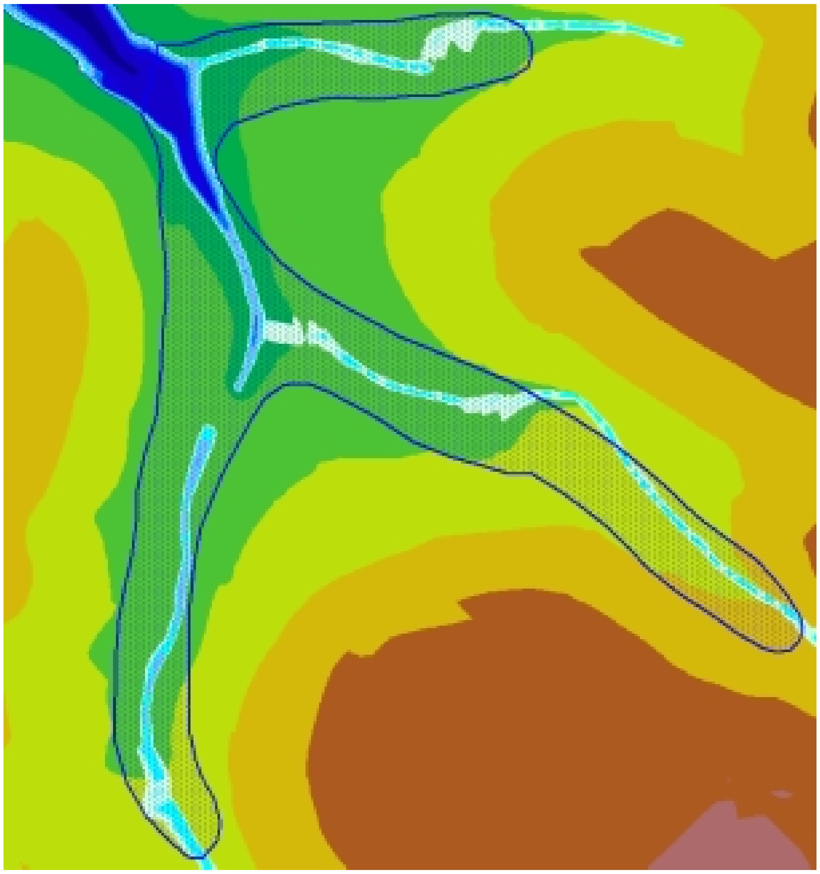


Figure 5.11 Floodplain Comparison

There is an obvious break in a segment of the lower stream. This occurs where the TIN used to delineate the floodplain depicts a road crossing. The pipe or culvert used to pass the flow underneath the road was not modeled in this study and could impact the upstream floodplain. Still, it is clear that the original Zone A is a very conservative approximation. Zone A is about 200 to 280 feet wide for the entire length of the streams, while the newly developed floodplains, upstream of the area influenced by Lake Travis, show an inundation area about 30 to 100 feet wide.

5.6 ARCGIS HYDRO DATA MODEL WITH DFIRM EXTENSION

Static structure Unified Modeling Language (UML) diagrams were developed for each of the five groups described in Section 4.11, which include Reference Information, Flood Data Features, Political and Transportation Features, Property Features, and Survey and Elevation Features. One example of these diagrams is shown below in Figure 5.12. All of the UML diagrams are included in Appendices B and C.

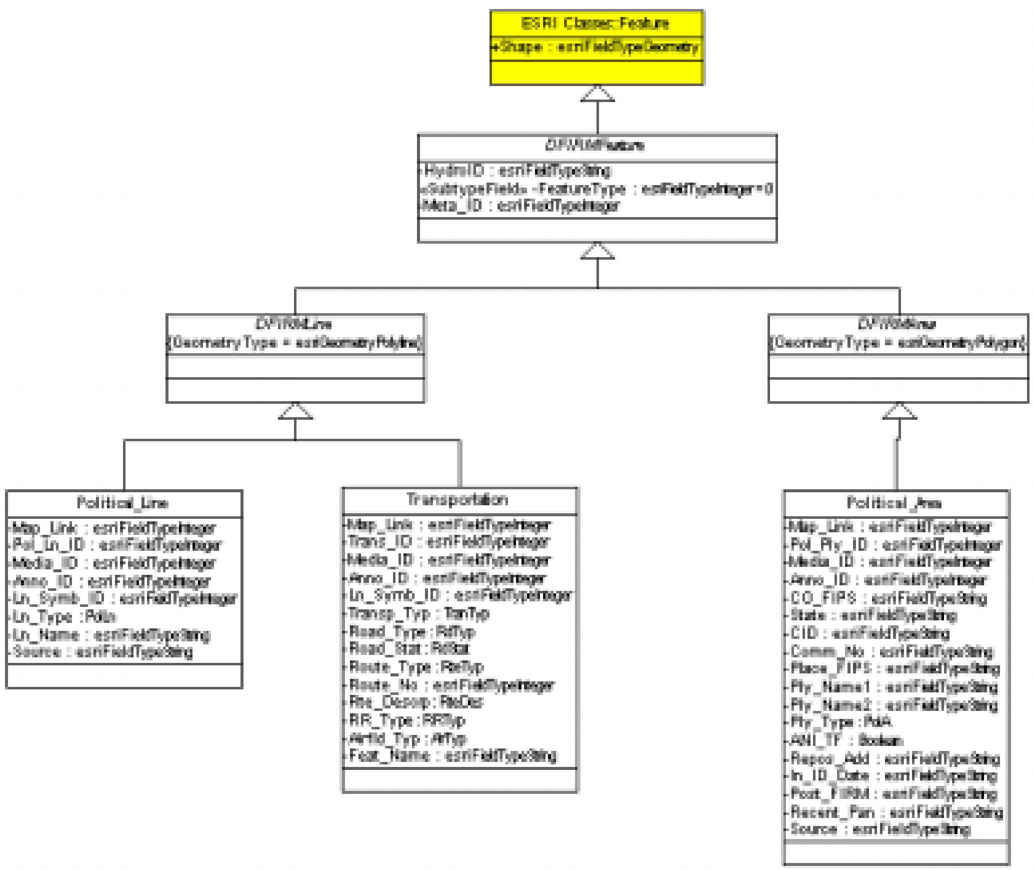


Figure 5.12 Political and Transportation Features UML Diagram

Figure 5.13 is an analysis diagram. Analysis diagrams display much of the same information as a UML static structure diagram, such as feature classes, attributes and relationships, but they leave off tagged values and attribute types. Additionally, analysis diagrams are just for display purposes and cannot be used to generate code like a UML diagram. Figure 5.13 displays the five different data groups discussed earlier. Figure 5.14 is zoomed in to show just the Political and Transportation Features diagram. All of the analysis diagrams are included in Appendix D.

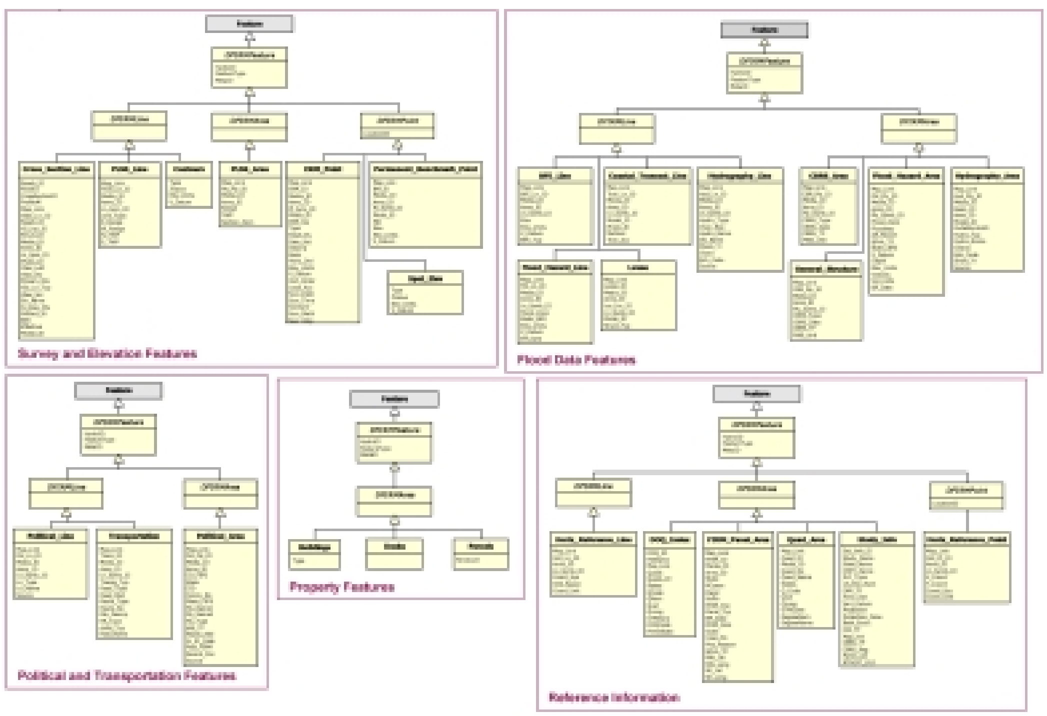


Figure 5.13 DFIRM Analysis Diagram

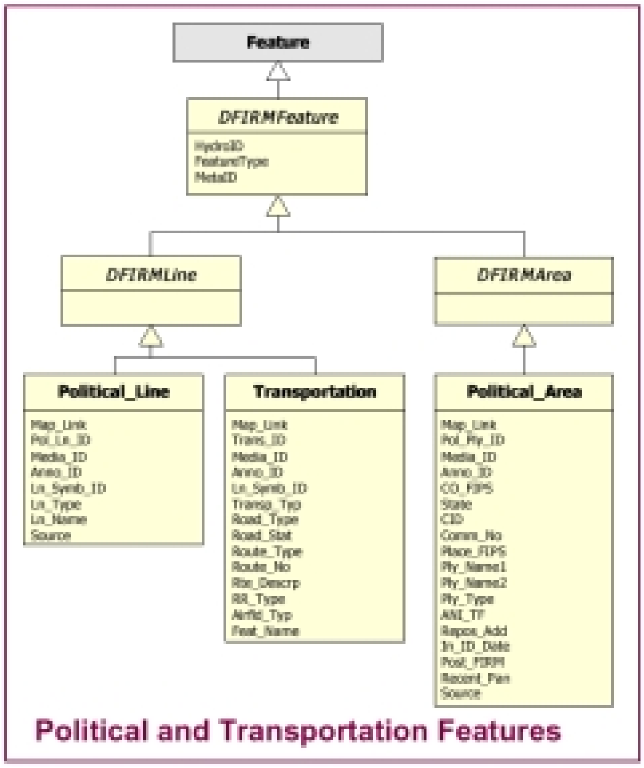


Figure 5.14 Political and Transportation Features Analysis Diagram

The ArcGIS Hydro Data Model with DFIRM Features Extension UML diagram was exported to a repository, named *DFIRM_ArcHydro.mdb*. It was then used to generate a geodatabase schema into which all of the DFIRM features, except the base map images, were loaded. At this time, the ArcGIS software is unable to load raster data into a geodatabase. Later versions of the software will have this capability.

The result is a single file called *LagoVistaDFIRM.mdb*, which can be opened and manipulated in both ArcMap and ArcCatalog. Individual feature classes can be loaded into ArcMap, without having to load the entire geodatabase. When the schema is applied, five feature datasets are created within the geodatabase. Four of these are feature datasets from the basic ArcGIS Hydro Data Model and the fifth is the DFIRM feature dataset. For more information regarding the ArcGIS Hydro data model and its characteristics, refer to the latest documentation available at http://www.crwr.utexas.edu/giswr.

Any feature datasets that are not being used can be erased without damaging any other part of the model, although classes with relationships will be affected. ArcMap was used to create a DFIRM map template where layouts, such as the one in Figure 5.8, were created for each of the 19 panels studied. The template allows the creation of panels with identical notes, title blocks and legends.

Chapter 6: Conclusions

6.1 INTRODUCTION

This research presents an approach for converting Flood Insurance Rate Maps used by the National Flood Insurance Program to digital format. GIS is used in the development of the base map imagery, redelineation of floodplains, manipulation and attribution of data, development of metadata, and the production of map panels. Available data relevant to floodplain mapping and management was assembled in a database and developed to meet DFIRM specifications.

Additionally, this study shows that GIS is an effective platform for the approximate analysis of flood zones, as well as the conversion of elevation data to a different vertical datum. A detailed description of original data, methods, and products are included in this report. The description can therefore be used as a guide for future DFIRM projects.

6.2 DFIRM PROGRAM

The DFIRM conversion program has many benefits to the National Flood Insurance Program. One of the primary benefits is that the cost of future revisions will greatly decrease. This study demonstrated how new elevation data can be used to redelineate a floodplain based upon an existing hydraulic study. If a DFIRM had already been in place for Lago Vista, the flood hazard areas could have been easily updated and replaced in the database without having to redo the base map information. More commonly, city expansion and land development near flood hazards will require new roads and buildings to be mapped. With a DFIRM in place, this involves the simple task of replacing the older information from the database and printing a new map.

Obtaining FIS reports and FIRM maps through the FEMA Map Service Center requires a fee and can take several days to be delivered. Digital versions of this information allow for fast, easy, and widespread distribution of information. DFIRMs have the capability to be viewed, printed, and downloaded off of the Internet.

This study found the assembly and modification of existing data and the development of new data, conforming to DFIRM standards, to be both time consuming and labor intensive. However, once a community or county has a completed DFIRM in place, the time spent on revision and maintenance of the data will be drastically reduced. Additionally, pilot projects like the study presented in this thesis should serve as guidance to future projects, reducing both the time and effort required.

This study is a successful demonstration of how some local groups, like the LCRA, can work with FEMA through the Cooperating Technical Community program. Community groups like the LCRA are ideally situated to assist FEMA in the development and maintenance of Flood Insurance Rate Maps. However, the number of local groups throughout the country that are in a position similar to the LCRA, having a large budget for data development and maintenance, is most likely limited.

This study also shows how improved data and new floodplain studies can benefit the public. By redelineating the 100-year floodplain of Lake Travis, this study has reduced the total number of buildings in Zone AE flood hazard areas by 865, from 1,833 to 968. Homeowners affected by this adjustment will see significant reductions in their insurance premiums. Improved data is also beneficial to the 74 homeowners that are now located in the 100-year floodplain. Although they may not like the increase in their flood insurance premiums, they are at least aware of their likelihood of being flooded. In the long run, it is much less expensive for a homeowner to pay flood insurance premiums than to pay for disaster assistance loans.

Redelineating the floodplain removed 47 percent of the buildings in the 100-year floodplain. At first glance, this is a surprisingly high percentage. Further thought reveals that buildings located within the 100-year floodplain are likely to be in close proximity to the floodplain boundary, for it is near the boundary that buildings are least likely to be flooded. Therefore, small changes in the floodplain extent can affect a large number of homeowners.

6.3 FURTHER IMPROVEMENTS

This study has shown how a GIS can be used to overcome some of the shortcomings of the FIRM process. Both detailed and approximate study methods used in the determination of flood elevations and floodplain delineation can be made more efficient using GIS. This study has demonstrated that, in some cases, Zone A flood hazard areas can be significantly over estimated when developed using "non-detailed" methods. It has also shown how contour data can be adjusted so that flood elevations based upon a different vertical datum can be accurately mapped.

FEMA seems to recognize the accuracy and efficiency that GIS can provide to hydrologic and hydraulic studies as well as the shortcomings of the Zone A areas. Recently, FEMA announced the addition of two new map modernization objectives: assessing available technologies to automate hydrologic and hydraulic modeling and floodplain delineation; and converting Zone A areas to detailed study areas where warranted and more accurately delineating Zone A areas where detailed studies are not warranted (FEMA, 2001).

6.4 DATA MODEL

The ArcGIS Hydro data model is designed to store the type of hydrologic, hydraulic, and topographic data that is often used to conduct a Flood Insurance Study and produce floodplains for display on a DFIRM. It seems logical to expand this data model to include all of the data stored in a DFIRM spatial database. This study has created an initial DFIRM extension to the ArcGIS Hydro data model. It demonstrates how a data model can help establish consistent and standard attribute fields, feature classes, and relationships. Future development and refinement of this ArcGIS Hydro DFIRM extension can be conducted so that DFIRM data is able to coexist with other national data models, such as that being developed for the Public Land Survey System, National Hydrography Dataset, National Elevation Dataset – Hydrologic Derivatives, and others.

The ArcGIS Hydro DFIRM extension can also be designed to assist in prioritizing which flood maps most need to be updated. Such a model is currently being developed for the Lower Colorado River Authority to help target their spending efforts. Similarly, a database called Mapping Needs Update Support System is being developed by FEMA to document all flood hazard map update needs nationwide. The Mapping Needs Update Support System will be used to rank and prioritize flood hazard map update needs. A Mapping Needs Update Support System component, which has relationships to the DFIRM, ArcGIS Hydro, and other databases, would be very valuable to the program.

Appendix A: Milestone 1

MILESTONE 1

Description of Proposed DFIRM Base Map Panels

The proposed DFIRM panels will replace the following paper FIRM maps:

48453C0350E	48453C0315E
48453C0355E	48453C0320E
48453C0360E	48453C0325E

The existing maps area at scale 1" = 800', while the new maps will be at scale 1"= 500' and 1"=1000'. Therefore, the area covered by the six (6) existing maps will be shown by 19 new maps.

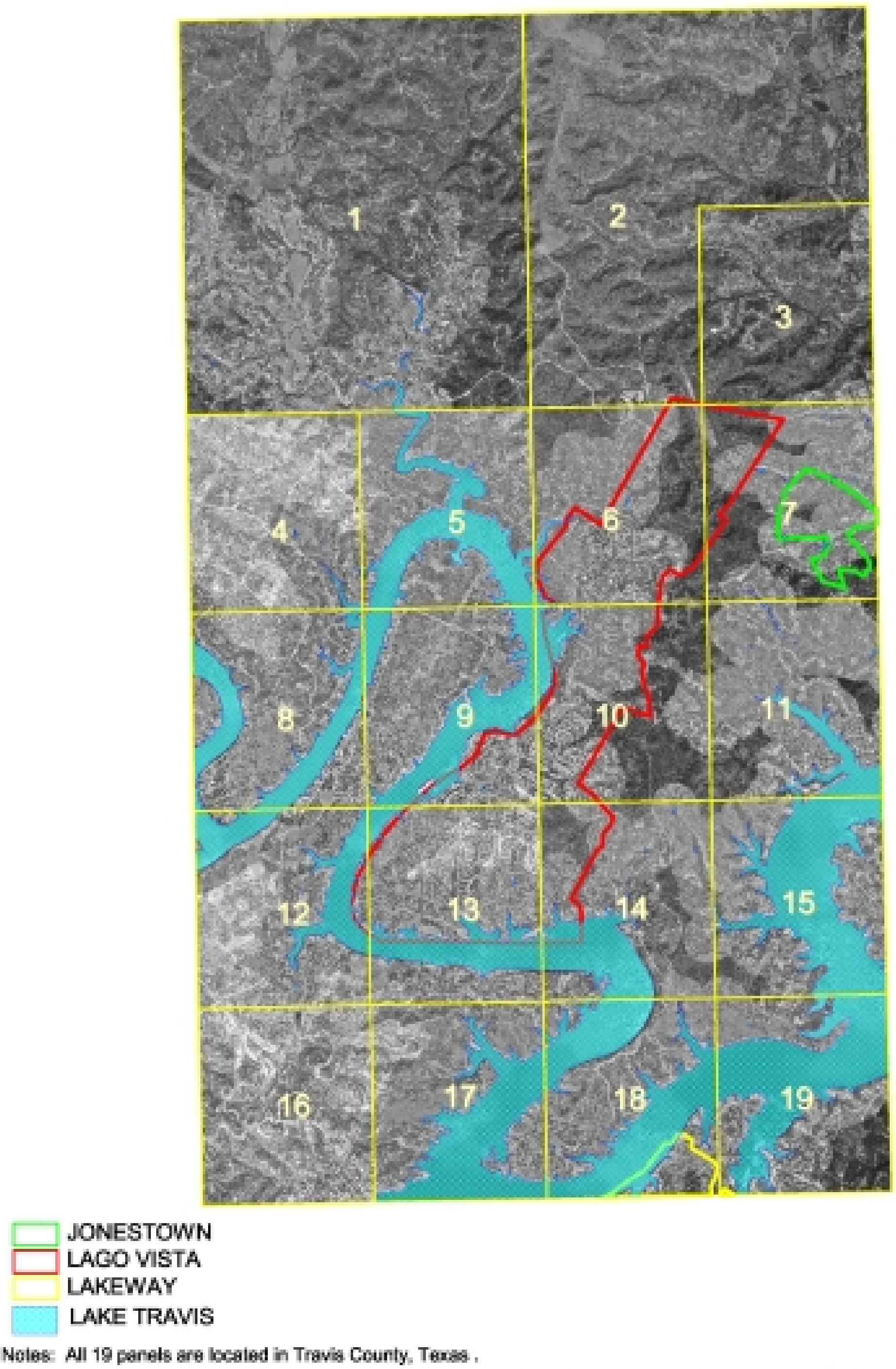
The following features will be shown on the new DFIRMs:

- An image file consisting of aerial photographs, obtained by the Lower Colorado River Authority, supplemented by USGS DOQQs
- Floodplain boundaries
- Hydrographic features
- Political boundaries, including corporate limits and extraterritorial jurisdictional areas
- Map panel neatlines
- Cross sections
- Elevation reference marks
- Test, including all road names near floodplains, political boundary labels, and other feature labels
- State Plane gridlines
- River miles

The following feature will be included in the data submission but will not appear on the DFIRM panels:

- Contours near Lake Travis
- Spot elevations near Lake Travis
- Outlines of buildings located near Lake Travis
- Outlines of parcel near Lake Travis
- Bridges
- Docks

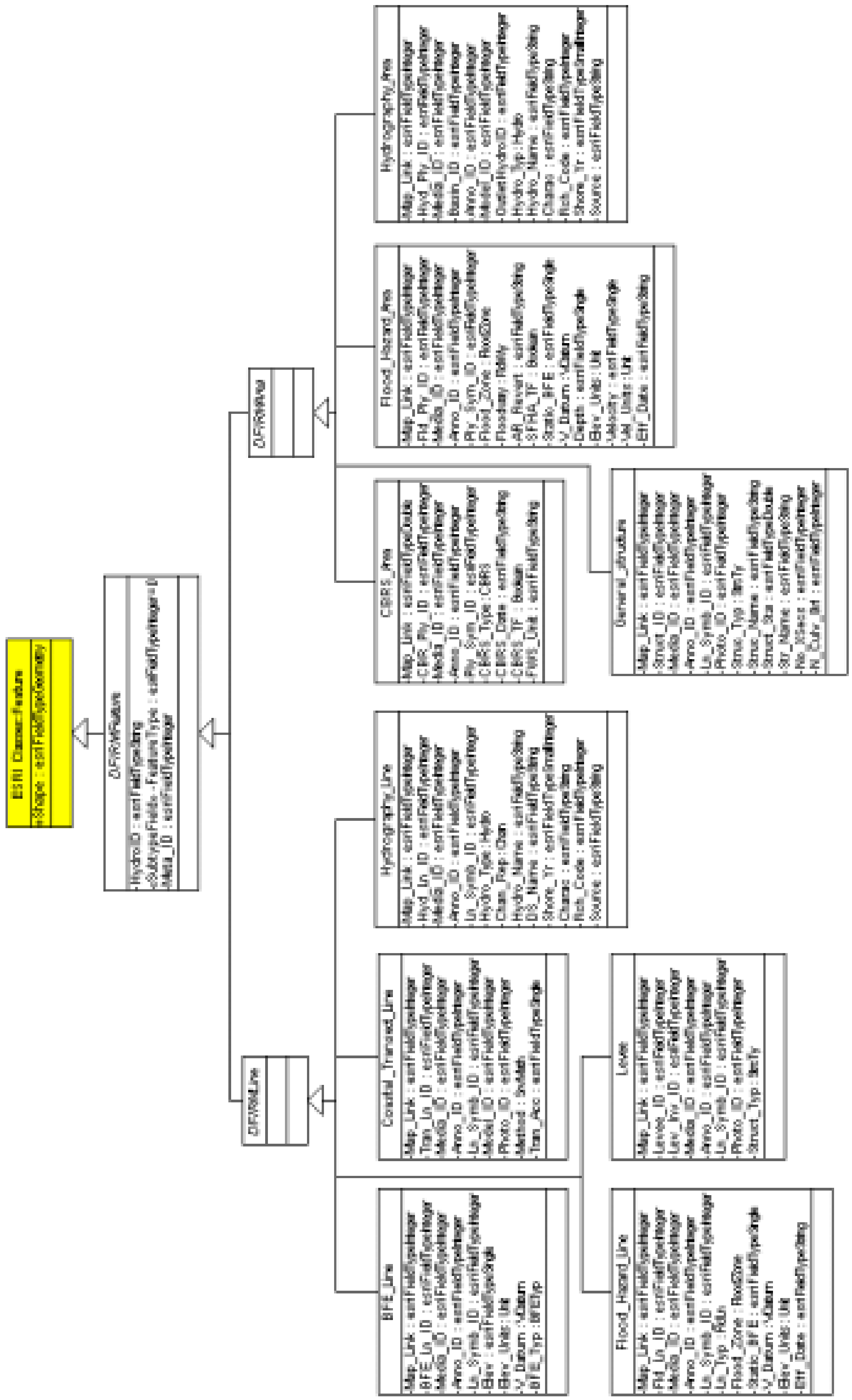
Proposed DFIRM Panel Layout



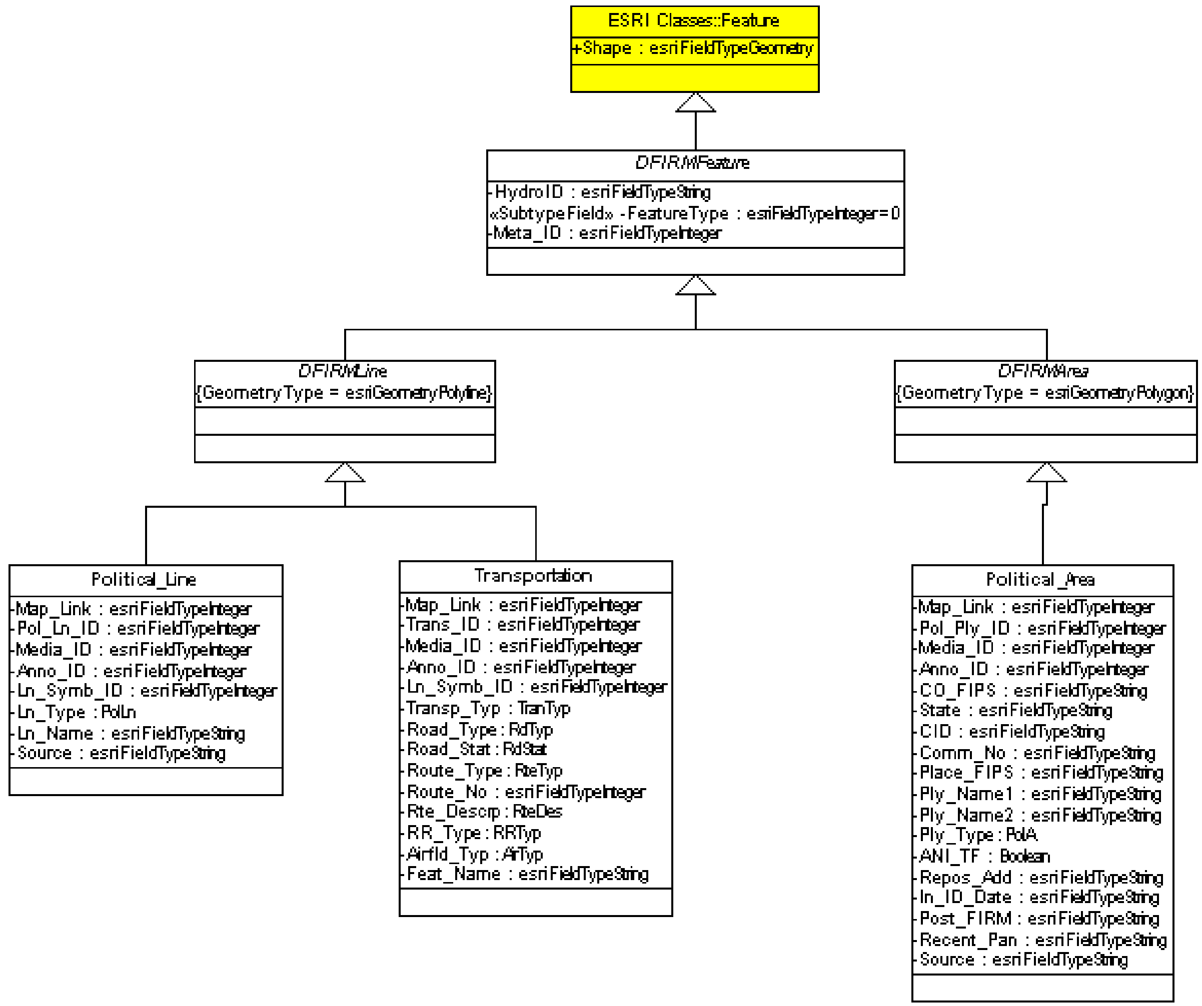
Notes: All 19 panels are located in Travis County, Texas .

Panels 1 and 2 will be produced at a scale of 1" = 1000'. All others will be prduced at a scale of 1" = 500'.

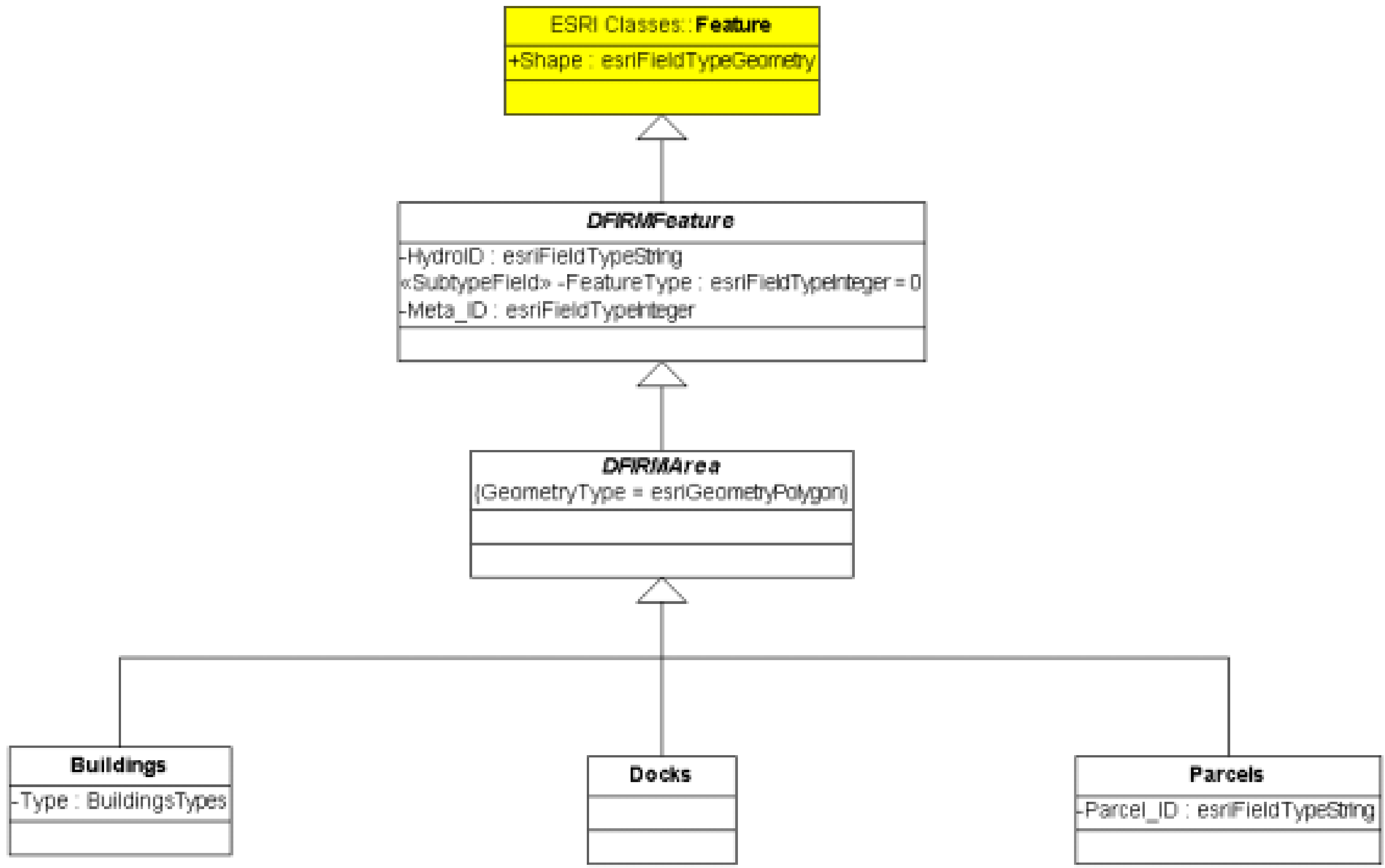
Appendix B: UML Static Structure Diagrams



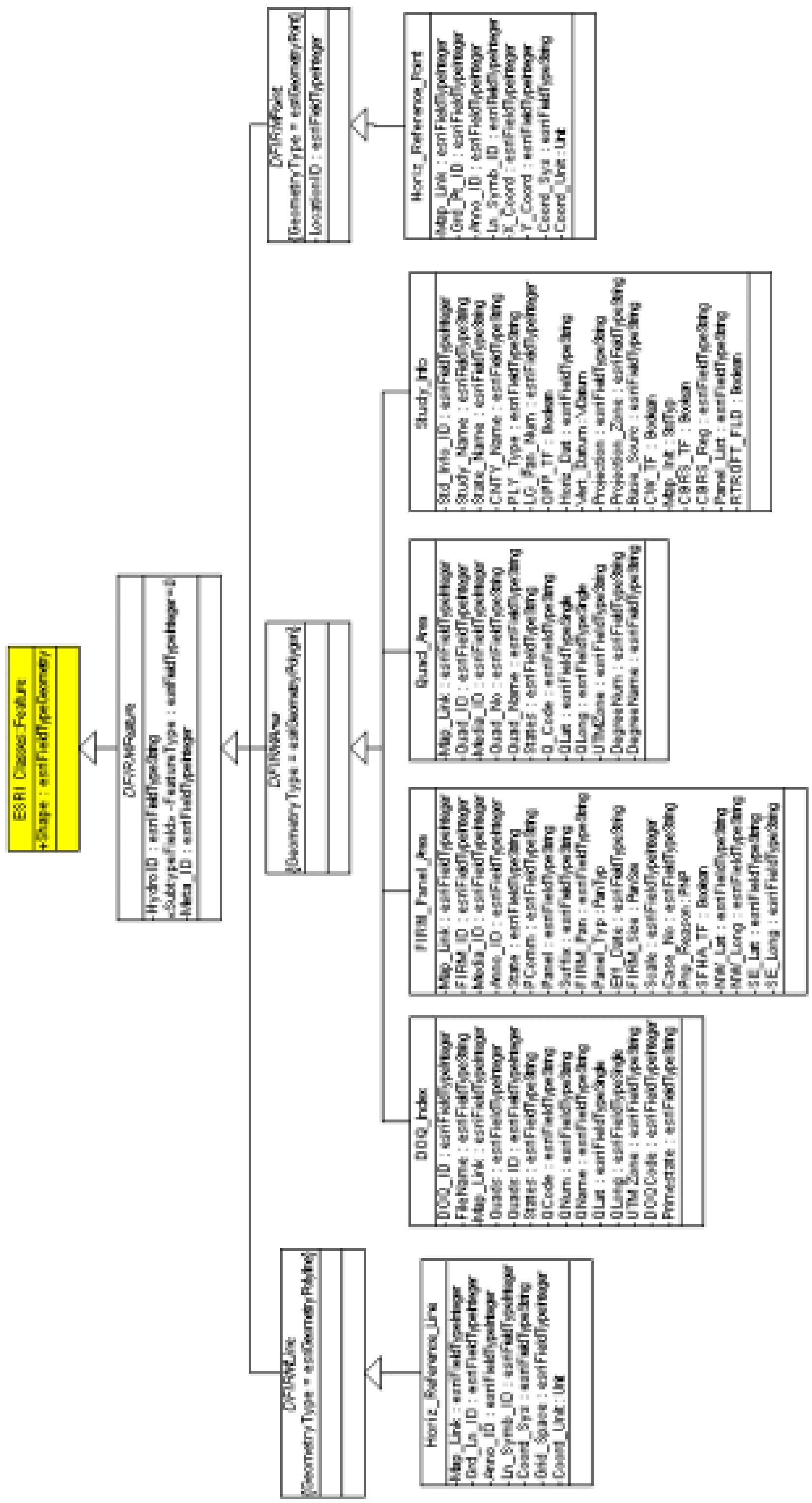
Flood Data Features



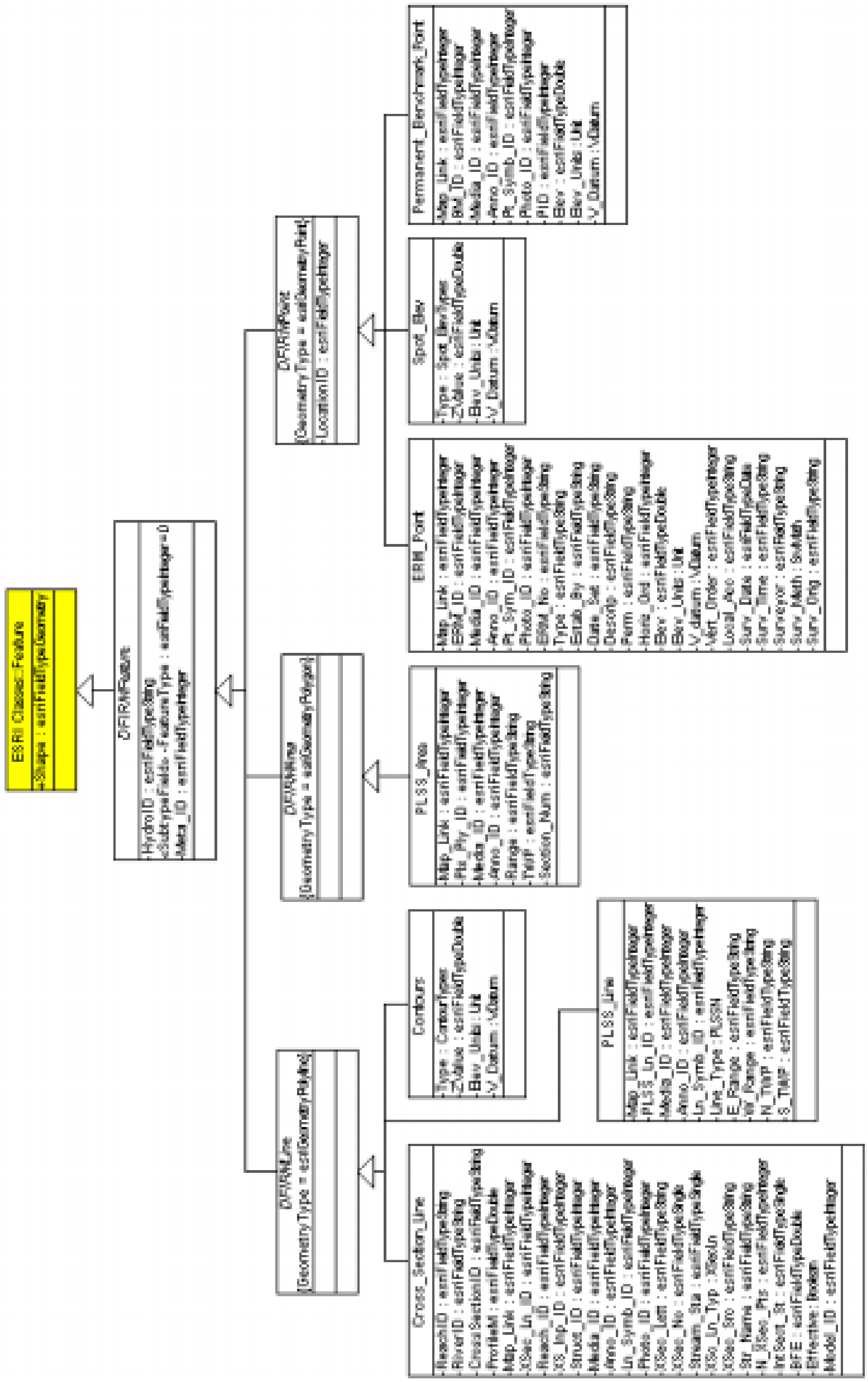
Political and Transportation Features



Property Features



Reference Information



Survey and Elevation Features

Appendix C: UML Coded Value Domains

«CodedValueDomain»
Hydro

+FieldType : <unspecified> = esriFieldTypeInteger
+MergePolicy : <unspecified> = esriMPTDefaultValue
+SplitPolicy : <unspecified> = esriSPTDefaultValue
+Perennial : esriFieldTypeSmallInteger = 1
+Braided : esriFieldTypeSmallInteger = 2
+Wash : esriFieldTypeSmallInteger = 3
+Shoreline : esriFieldTypeSmallInteger = 4
+ManMade : esriFieldTypeSmallInteger = 5
+Lake : esriFieldTypeSmallInteger = 6
+Reservoir : esriFieldTypeSmallInteger = 7
+Ditch : esriFieldTypeSmallInteger = 8
+Aquaduct : esriFieldTypeSmallInteger = 9
+Channel : esriFieldTypeSmallInteger = 10
+Race : esriFieldTypeSmallInteger = 11
+Gulch : esriFieldTypeSmallInteger = 12
+Penstock : esriFieldTypeSmallInteger = 13
+Waterfall : esriFieldTypeSmallInteger = 14
+Hatchery : esriFieldTypeSmallInteger = 15
+Tailings_Pond : esriFieldTypeSmallInteger = 16
+Flume : esriFieldTypeSmallInteger = 17
+Bog : esriFieldTypeSmallInteger = 18
+Swamp : esriFieldTypeSmallInteger = 19
+Glacier : esriFieldTypeSmallInteger = 20
+Retention_Pond : esriFieldTypeSmallInteger = 21

«CodedValueDomain»
PolLn

+FieldType : <unspecified> = esriFieldTypeInteger
+MergePolicy : <unspecified> = esriMPTDefaultValue
+SplitPolicy : <unspecified> = esriSPTDefaultValue
+Corporate : esriFieldTypeSmallInteger = 1
+County : esriFieldTypeSmallInteger = 2
+State : esriFieldTypeSmallInteger = 3
+US : esriFieldTypeSmallInteger = 4
+ETJ : esriFieldTypeSmallInteger = 5
+ANI : esriFieldTypeSmallInteger = 6
+Special : esriFieldTypeSmallInteger = 7
+Urban : esriFieldTypeSmallInteger = 8

«CodedValueDomain»
PolStat

+FieldType : <unspecified> = esriFieldTypeInteger
+MergePolicy : <unspecified> = esriMPTDefaultValue
+SplitPolicy : <unspecified> = esriSPTDefaultValue
+Indef : esriFieldTypeSmallInteger = 1
+Approx : esriFieldTypeSmallInteger = 2
+Disputed : esriFieldTypeSmallInteger = 3

«CodedValueDomain»
PanTyp

+FieldType : <unspecified> = esriFieldTypeInteger
+MergePolicy : <unspecified> = esriMPTDefaultValue
+SplitPolicy : <unspecified> = esriSPTDefaultValue
+CWPP : esriFieldTypeSmallInteger = 1
+CWNP : esriFieldTypeSmallInteger = 2
+CBPP : esriFieldTypeSmallInteger = 3
+CBNP : esriFieldTypeSmallInteger = 4
+AOPN : esriFieldTypeSmallInteger = 5
+UNMC : esriFieldTypeSmallInteger = 6
+Water : esriFieldTypeSmallInteger = 7

«CodedValueDomain»
PNP

+FieldType : <unspecified> = esriFieldTypeInteger
+MergePolicy : <unspecified> = esriMPTDefaultValue
+SplitPolicy : <unspecified> = esriSPTDefaultValue
+All_D : esriFieldTypeSmallInteger = 1
+Open_Water : esriFieldTypeSmallInteger = 2
+NSFHA : esriFieldTypeSmallInteger = 3
+ANI : esriFieldTypeSmallInteger = 4
+All_AE : esriFieldTypeSmallInteger = 5
+All_A : esriFieldTypeSmallInteger = 6
+All_VE : esriFieldTypeSmallInteger = 7
+All_V : esriFieldTypeSmallInteger = 8
+Outside_Corp : esriFieldTypeSmallInteger = 9
+Outside_County : esriFieldTypeSmallInteger = 10
+No_FW : esriFieldTypeSmallInteger = 11

«CodedValueDomain»
PolA

+FieldType : <unspecified> = esriFieldTypeInteger
+MergePolicy : <unspecified> = esriMPTDefaultValue
+SplitPolicy : <unspecified> = esriSPTDefaultValue
+Corporate : esriFieldTypeSmallInteger = 1
+Unincorporated : esriFieldTypeSmallInteger = 2
+Indian : esriFieldTypeSmallInteger = 3
+Military : esriFieldTypeSmallInteger = 4
+State_Forest : esriFieldTypeSmallInteger = 5
+ANI : esriFieldTypeSmallInteger = 6
+Nat_Park : esriFieldTypeSmallInteger = 7
+Nat_Scenic_Area : esriFieldTypeSmallInteger = 8
+Fed_Prison : esriFieldTypeSmallInteger = 9
+Fed_Reserv : esriFieldTypeSmallInteger = 10
+State_Resev : esriFieldTypeSmallInteger = 11
+State_Prison : esriFieldTypeSmallInteger = 12
+State_Wildlife_Ref : esriFieldTypeSmallInteger = 13
+County_Game_Pres : esriFieldTypeSmallInteger = 14
+Barrio : esriFieldTypeSmallInteger = 15
+Hawaiian_Home : esriFieldTypeSmallInteger = 16

«CodedValueDomain» **RdTyp**
+FieldType : <unspecified> = esriFieldTypeInteger
+MergePolicy : <unspecified> = esriMPTDefaultValue
+SplitPolicy : <unspecified> = esriSPTDefaultValue
+Primary : esriFieldTypeSmallInteger = 1
+Secondary : esriFieldTypeSmallInteger = 2
+Trail : esriFieldTypeSmallInteger = 3
+Road_Bridge : esriFieldTypeSmallInteger = 4
+Road_Tunnel : esriFieldTypeSmallInteger = 5
+Footbridge : esriFieldTypeSmallInteger = 6
+Ford : esriFieldTypeSmallInteger = 7

«CodedValueDomain» **RdStat**
+FieldType : <unspecified> = esriFieldTypeInteger
+MergePolicy : <unspecified> = esriMPTDefaultValue
+SplitPolicy : <unspecified> = esriSPTDefaultValue
+Paved : esriFieldTypeSmallInteger = 1
+Unimproved : esriFieldTypeSmallInteger = 2
+Under_Construc : esriFieldTypeSmallInteger = 3

«CodedValueDomain» **PLSSN**
+FieldType : <unspecified> = esriFieldTypeInteger
+MergePolicy : <unspecified> = esriMPTDefaultValue
+SplitPolicy : <unspecified> = esriSPTDefaultValue
+Range : esriFieldTypeSmallInteger = 1
+Township : esriFieldTypeSmallInteger = 2
+Section : esriFieldTypeSmallInteger = 3
+Qtr_Section : esriFieldTypeSmallInteger = 4

«CodedValueDomain» **StdTyp**
+FieldType : <unspecified> = esriFieldTypeInteger
+MergePolicy : <unspecified> = esriMPTDefaultValue
+SplitPolicy : <unspecified> = esriSPTDefaultValue
+Map Initiatives : esriFieldTypeSmallInteger = 1
+Partial Map Initiatives : esriFieldTypeSmallInteger = 2
+FIRM-FBFM : esriFieldTypeSmallInteger = 3

«CodedValueDomain» **ResrTE**
+FieldType : <unspecified> = esriFieldTypeInteger
+MergePolicy : <unspecified> = esriMPTDefaultValue
+SplitPolicy : <unspecified> = esriSPTDefaultValue
+Res_Stor_Vol : esriFieldTypeSmallInteger = 1
+Res_Stor_Area : esriFieldTypeSmallInteger = 2
+Res_Stor_Elev : esriFieldTypeSmallInteger = 3
+Res_Out_Elev : esriFieldTypeSmallInteger = 4
+Res_Out_Q : esriFieldTypeSmallInteger = 5
+Res_Out_Outlet : esriFieldTypeSmallInteger = 6
+Res_Out_Spillway : esriFieldTypeSmallInteger = 7
+Res_Out_TpoDam : esriFieldTypeSmallInteger = 8
+Res_Out_CrestL : esriFieldTypeSmallInteger = 9
+Res_Out_Ogee : esriFieldTypeSmallInteger = 10

«CodedValueDomain» **PanSze**
+FieldType : <unspecified> = esriFieldTypeInteger
+MergePolicy : <unspecified> = esriMPTDefaultValue
+SplitPolicy : <unspecified> = esriSPTDefaultValue
+A : esriFieldTypeSmallInteger = 1
+B : esriFieldTypeSmallInteger = 2
+C : esriFieldTypeSmallInteger = 3
+D : esriFieldTypeSmallInteger = 4
+E : esriFieldTypeSmallInteger = 5
+8x11 : esriFieldTypeSmallInteger = 6
+11x17 : esriFieldTypeSmallInteger = 7

«CodedValueDomain» **StrcTy**
+FieldType : <unspecified> = esriFieldTypeInteger
+MergePolicy : <unspecified> = esriMPTDefaultValue
+SplitPolicy : <unspecified> = esriSPTDefaultValue
+CU : esriFieldTypeSmallInteger = 1
+BR : esriFieldTypeSmallInteger = 2
+WR : esriFieldTypeSmallInteger = 3
+DM : esriFieldTypeSmallInteger = 4
+DI : esriFieldTypeSmallInteger = 5
+GT : esriFieldTypeSmallInteger = 6
+LV : esriFieldTypeSmallInteger = 7

«CodedValueDomain» **CBRDat**
+FieldType : <unspecified> = esriFieldTypeInteger
+MergePolicy : <unspecified> = esriMPTDefaultValue
+SplitPolicy : <unspecified> = esriSPTDefaultValue

«CodedValueDomain»
AirTyp

+FieldType : <unspecified> = esriFieldTypeInteger
+MergePolicy : <unspecified> = esriMPTDefaultValue
+SplitPolicy : <unspecified> = esriSPTDefaultValue
+Airport : esriFieldTypeSmallInteger = 1
+Airfield : esriFieldTypeSmallInteger = 2
+Landing_Strip : esriFieldTypeSmallInteger = 3
+Heliport : esriFieldTypeSmallInteger = 4
+Launch_Complex : esriFieldTypeSmallInteger = 5

«CodedValueDomain»
BFETyp

+FieldType : <unspecified> = esriFieldTypeInteger
+MergePolicy : <unspecified> = esriMPTDefaultValue
+SplitPolicy : <unspecified> = esriSPTDefaultValue
+Drafted : esriFieldTypeSmallInteger = 1
+Interp : esriFieldTypeSmallInteger = 2
+Calc : esriFieldTypeSmallInteger = 3

«CodedValueDomain»
RteDes

+FieldType : <unspecified> = esriFieldTypeInteger
+MergePolicy : <unspecified> = esriMPTDefaultValue
+SplitPolicy : <unspecified> = esriSPTDefaultValue
+ALT : esriFieldTypeSmallInteger = 1
+BYP : esriFieldTypeSmallInteger = 2
+OLD : esriFieldTypeSmallInteger = 3
+N : esriFieldTypeSmallInteger = 4
+S : esriFieldTypeSmallInteger = 5
+E : esriFieldTypeSmallInteger = 6
+W : esriFieldTypeSmallInteger = 7

«CodedValueDomain»
Chan

+FieldType : <unspecified> = esriFieldTypeInteger
+MergePolicy : <unspecified> = esriMPTDefaultValue
+SplitPolicy : <unspecified> = esriSPTDefaultValue
+Single : esriFieldTypeSmallInteger = 1
+Double : esriFieldTypeSmallInteger = 2

«CodedValueDomain»
HDatum

+FieldType : <unspecified> = esriFieldTypeInteger
+MergePolicy : <unspecified> = esriMPTDefaultValue
+SplitPolicy : <unspecified> = esriSPTDefaultValue

«CodedValueDomain»
FldWy

+FieldType : <unspecified> = esriFieldTypeInteger
+MergePolicy : <unspecified> = esriMPTDefaultValue
+SplitPolicy : <unspecified> = esriSPTDefaultValue
+FW : esriFieldTypeSmallInteger = 1
+Ease : esriFieldTypeSmallInteger = 2
+State : esriFieldTypeSmallInteger = 3

«CodedValueDomain»
RRTyp

+FieldType : <unspecified> = esriFieldTypeInteger
+MergePolicy : <unspecified> = esriMPTDefaultValue
+SplitPolicy : <unspecified> = esriSPTDefaultValue
+Active : esriFieldTypeSmallInteger = 1
+Abandoned : esriFieldTypeSmallInteger = 2
+Dismantled : esriFieldTypeSmallInteger = 3
+RR_Yard : esriFieldTypeSmallInteger = 4
+RR_Tunnel : esriFieldTypeSmallInteger = 5
+RR_Bridge : esriFieldTypeSmallInteger = 6
+Cog_RR : esriFieldTypeSmallInteger = 7
+Tram : esriFieldTypeSmallInteger = 8
+Rapid_Transit : esriFieldTypeSmallInteger = 9
+Logging : esriFieldTypeSmallInteger = 10
+Narrow_Gauge : esriFieldTypeSmallInteger = 11

«CodedValueDomain»
RteTyp

+FieldType : <unspecified> = esriFieldTypeInteger
+MergePolicy : <unspecified> = esriMPTDefaultValue
+SplitPolicy : <unspecified> = esriSPTDefaultValue
+Interstate : esriFieldTypeSmallInteger = 1
+US : esriFieldTypeSmallInteger = 2
+State : esriFieldTypeSmallInteger = 3
+County : esriFieldTypeSmallInteger = 4
+Local : esriFieldTypeSmallInteger = 5
+Private : esriFieldTypeSmallInteger = 6

«CodedValueDomain»
TranTyp

+FieldType : <unspecified> = esriFieldTypeInteger
+MergePolicy : <unspecified> = esriMPTDefaultValue
+SplitPolicy : <unspecified> = esriSPTDefaultValue
+Road : esriFieldTypeSmallInteger = 1
+Railroad : esriFieldTypeSmallInteger = 2
+Airport : esriFieldTypeSmallInteger = 3
+Ferry : esriFieldTypeSmallInteger = 4

«CodedValueDomain»
SrvMeth

+FieldType : <unspecified> = esriFieldTypeInteger
+MergePolicy : <unspecified> = esriMPTDefaultValue
+SplitPolicy : <unspecified> = esriSPTDefaultValue
+GPS 2cm : esriFieldTypeSmallInteger = 1
+GPS 5cm : esriFieldTypeSmallInteger = 2
+Leveling 1st order class I : esriFieldTypeSmallInteger = 3
+Leveling 1st order class II : esriFieldTypeSmallInteger = 4
+Leveling 2nd order class I : esriFieldTypeSmallInteger = 5
+Leveling 2nd order class II : esriFieldTypeSmallInteger = 6
+Leveling 3rd order : esriFieldTypeSmallInteger = 7

«CodedValueDomain»
ContourTypes

+FieldType : <unspecified> = esriFieldTypeInteger
+MergePolicy : <unspecified> = esriMPTDefaultValue
+SplitPolicy : <unspecified> = esriSPTDefaultValue
+Index : esriFieldTypeSmallInteger = 1
+Hidden Index : esriFieldTypeSmallInteger = 2
-Dense Woods Index : esriFieldTypeSmallInteger = 3
+Intermediate : esriFieldTypeSmallInteger = 4
+Hidden Intermediate : esriFieldTypeSmallInteger = 5
+Dense Woods Intermediate : esriFieldTypeSmallInteger = 6

«CodedValueDomain»
VDatum

+FieldType : <unspecified> = esriFieldTypeInteger
+MergePolicy : <unspecified> = esriMPTDefaultValue
+SplitPolicy : <unspecified> = esriSPTDefaultValue
+NGVD29 : esriFieldTypeSmallInteger = 1
+NAVD88 : esriFieldTypeSmallInteger = 2
+MSL : esriFieldTypeSmallInteger = 3
+Other : esriFieldTypeSmallInteger = 4

«CodedValueDomain»
XSecLn

+FieldType : <unspecified> = esriFieldTypeInteger
+MergePolicy : <unspecified> = esriMPTDefaultValue
+SplitPolicy : <unspecified> = esriSPTDefaultValue
+Modeled : esriFieldTypeSmallInteger = 1
+Graphic : esriFieldTypeSmallInteger = 2

«CodedValueDomain»
FldLn

+FieldType : <unspecified> = esriFieldTypeInteger
+MergePolicy : <unspecified> = esriMPTDefaultValue
+SplitPolicy : <unspecified> = esriSPTDefaultValue
+100 : esriFieldTypeSmallInteger = 1
+500 : esriFieldTypeSmallInteger = 2
+FW : esriFieldTypeSmallInteger = 3
+Ease : esriFieldTypeSmallInteger = 4
+State : esriFieldTypeSmallInteger = 5
+LODS : esriFieldTypeSmallInteger = 6
+LOS : esriFieldTypeSmallInteger = 7
+LOF : esriFieldTypeSmallInteger = 8
+Zone_Break : esriFieldTypeSmallInteger = 9
+Apparent_Limit : esriFieldTypeSmallInteger = 10
+County : esriFieldTypeSmallInteger = 11
+Corporate : esriFieldTypeSmallInteger = 12

«CodedValueDomain»
BuildingsTypes

+FieldType : <unspecified> = esriFieldTypeInteger
+MergePolicy : <unspecified> = esriMPTDefaultValue
+SplitPolicy : <unspecified> = esriSPTDefaultValue
+Building : esriFieldTypeSmallInteger = 1
+Trailer : esriFieldTypeSmallInteger = 2

«CodedValueDomain»
Spot_ElevTypes

+FieldType : <unspecified> = esriFieldTypeInteger
+MergePolicy : <unspecified> = esriMPTDefaultValue
+SplitPolicy : <unspecified> = esriSPTDefaultValue
+Spot Elevation : esriFieldTypeSmallInteger = 1
+Bridge Spot Elevation : esriFieldTypeSmallInteger = 2

«CodedValueDomain»
CBRS

+FieldType : <unspecified> = esriFieldTypeInteger
+MergePolicy : <unspecified> = esriMPTDefaultValue
+SplitPolicy : <unspecified> = esriSPTDefaultValue
-1983 : esriFieldTypeSmallInteger = 1
-OPA : esriFieldTypeSmallInteger = 2

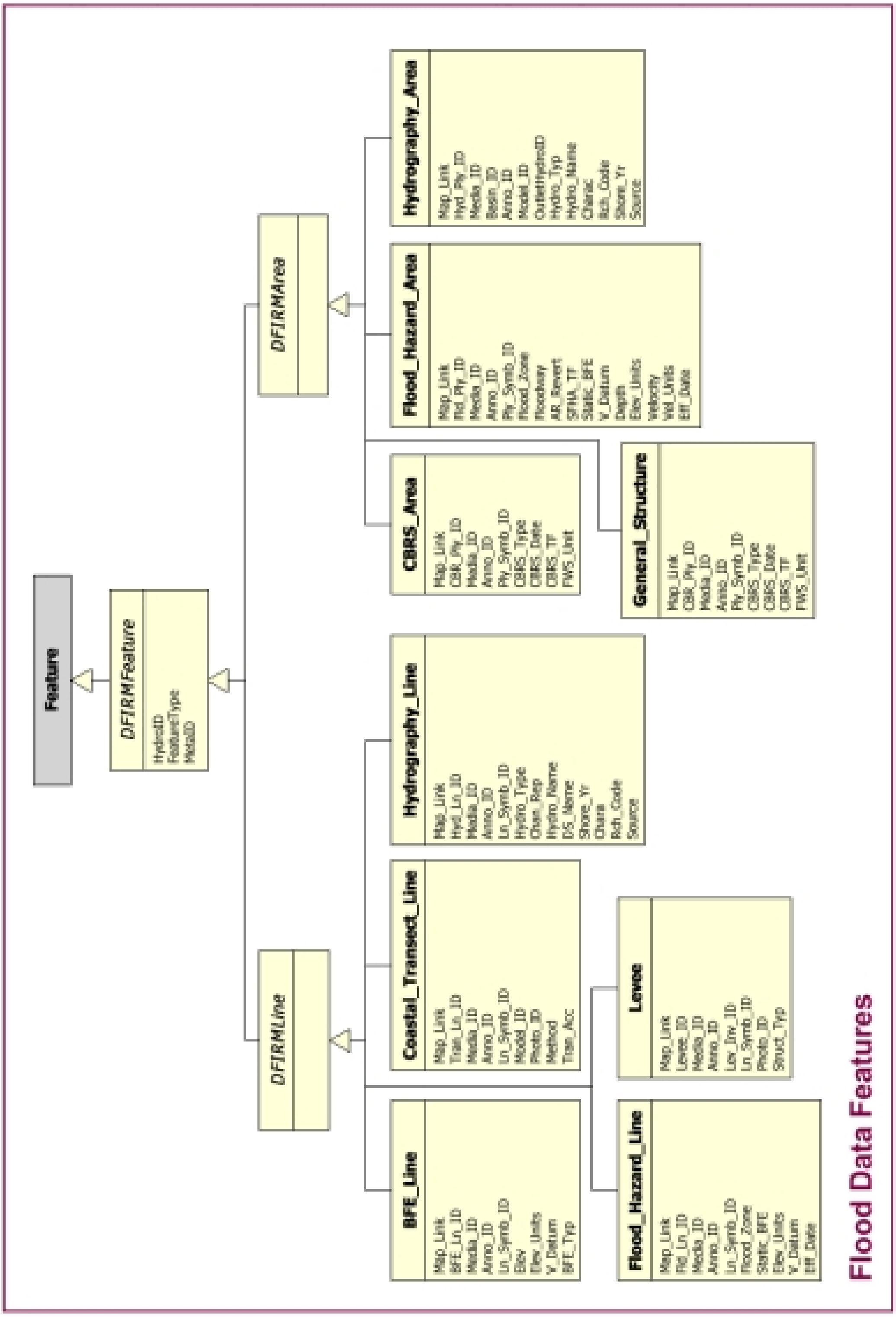
«CodedValueDomain»
Unit

+FieldType : <unspecified> = esriFieldTypeInteger
+MergePolicy : <unspecified> = esriMPTDefaultValue
+SplitPolicy : <unspecified> = esriSPTDefaultValue
-DMS : esriFieldTypeSmallInteger = 1
-DD : esriFieldTypeSmallInteger = 2
-DEC_MIN : esriFieldTypeSmallInteger = 3
-DEC_SEC : esriFieldTypeSmallInteger = 4
-DEG_DEC_MI : esriFieldTypeSmallInteger = 5
-GRAD : esriFieldTypeSmallInteger = 6
-ACRES : esriFieldTypeSmallInteger = 7
-ACRE_FT : esriFieldTypeSmallInteger = 8
-CC : esriFieldTypeSmallInteger = 9
-CC_HR : esriFieldTypeSmallInteger = 10
-CC_MIN : esriFieldTypeSmallInteger = 11
-CC_SEC : esriFieldTypeSmallInteger = 12
-CF : esriFieldTypeSmallInteger = 13
-CF_HR : esriFieldTypeSmallInteger = 14
-CF_MIN : esriFieldTypeSmallInteger = 15
-CF_SEC : esriFieldTypeSmallInteger = 16
-CM : esriFieldTypeSmallInteger = 17
-CM_DAY : esriFieldTypeSmallInteger = 18
-CM_HR : esriFieldTypeSmallInteger = 19
-CM2 : esriFieldTypeSmallInteger = 20
-CY : esriFieldTypeSmallInteger = 21
-DDMMSS : esriFieldTypeSmallInteger = 22
-DEG : esriFieldTypeSmallInteger = 23
-FT : esriFieldTypeSmallInteger = 24
-FT_DAY : esriFieldTypeSmallInteger = 25
-FT_HR : esriFieldTypeSmallInteger = 26
-FT_MIN : esriFieldTypeSmallInteger = 27
-FT_MO : esriFieldTypeSmallInteger = 28
-FT_SEC : esriFieldTypeSmallInteger = 29
-FT_YR : esriFieldTypeSmallInteger = 30
-GPD : esriFieldTypeSmallInteger = 31
-GPH : esriFieldTypeSmallInteger = 32
-GPM : esriFieldTypeSmallInteger = 33
-GPS : esriFieldTypeSmallInteger = 34
-HA : esriFieldTypeSmallInteger = 35
-HHMMSS : esriFieldTypeSmallInteger = 36
-IN : esriFieldTypeSmallInteger = 37
-IN_DAY : esriFieldTypeSmallInteger = 38
-IN_HG : esriFieldTypeSmallInteger = 39
-IN_HR : esriFieldTypeSmallInteger = 40
-IN_MIN : esriFieldTypeSmallInteger = 41
-IN_MO : esriFieldTypeSmallInteger = 42
-IN_SEC : esriFieldTypeSmallInteger = 43
-IN_YR : esriFieldTypeSmallInteger = 44
-KG : esriFieldTypeSmallInteger = 45
-KG_HR : esriFieldTypeSmallInteger = 46
-KG_MIN : esriFieldTypeSmallInteger = 47
-KG_SEC : esriFieldTypeSmallInteger = 48
-KM : esriFieldTypeSmallInteger = 49
-KM_HR : esriFieldTypeSmallInteger = 50
-KM2 : esriFieldTypeSmallInteger = 51
-L : esriFieldTypeSmallInteger = 52
-L_HR : esriFieldTypeSmallInteger = 53
-L_MIN : esriFieldTypeSmallInteger = 54
-L_SEC : esriFieldTypeSmallInteger = 55
-LB : esriFieldTypeSmallInteger = 56
-LEAGUE : esriFieldTypeSmallInteger = 57
-M : esriFieldTypeSmallInteger = 58
-M_HR : esriFieldTypeSmallInteger = 59
-M_MIN : esriFieldTypeSmallInteger = 60
-M_SEC : esriFieldTypeSmallInteger = 61
-M3_MIN : esriFieldTypeSmallInteger = 64
-M3_SEC : esriFieldTypeSmallInteger = 65
-MGAL_DAY : esriFieldTypeSmallInteger = 66
-MI : esriFieldTypeSmallInteger = 67
-MI2 : esriFieldTypeSmallInteger = 68
-MI3 : esriFieldTypeSmallInteger = 69
-MINLAT : esriFieldTypeSmallInteger = 70
-MINUTES : esriFieldTypeSmallInteger = 71
-ML : esriFieldTypeSmallInteger = 72
-MM : esriFieldTypeSmallInteger = 73
-MM2 : esriFieldTypeSmallInteger = 74
-MM3 : esriFieldTypeSmallInteger = 75
-MPH : esriFieldTypeSmallInteger = 76
-NM : esriFieldTypeSmallInteger = 77
-PCT : esriFieldTypeSmallInteger = 78
-PPB : esriFieldTypeSmallInteger = 79
-PPM : esriFieldTypeSmallInteger = 80
-PPT : esriFieldTypeSmallInteger = 81
-PPTH : esriFieldTypeSmallInteger = 82
-PSI : esriFieldTypeSmallInteger = 83
-RAD : esriFieldTypeSmallInteger = 84
-RATIO : esriFieldTypeSmallInteger = 85
-RN_IN_DAY : esriFieldTypeSmallInteger = 86
-RN_IN_HR : esriFieldTypeSmallInteger = 87
-RN_IN_YR : esriFieldTypeSmallInteger = 88
-SEC : esriFieldTypeSmallInteger = 89
-SF : esriFieldTypeSmallInteger = 90
-SI : esriFieldTypeSmallInteger = 91
-SN_IN_DAY : esriFieldTypeSmallInteger = 92
-SN_IN_HR : esriFieldTypeSmallInteger = 93
-SN_IN_YR : esriFieldTypeSmallInteger = 94
-TBD : esriFieldTypeSmallInteger = 95
-UNKNOWN : esriFieldTypeSmallInteger = 96
-USGAL : esriFieldTypeSmallInteger = 97
-YD : esriFieldTypeSmallInteger = 98
-YD2 : esriFieldTypeSmallInteger = 99
-DPI : esriFieldTypeSmallInteger = 100

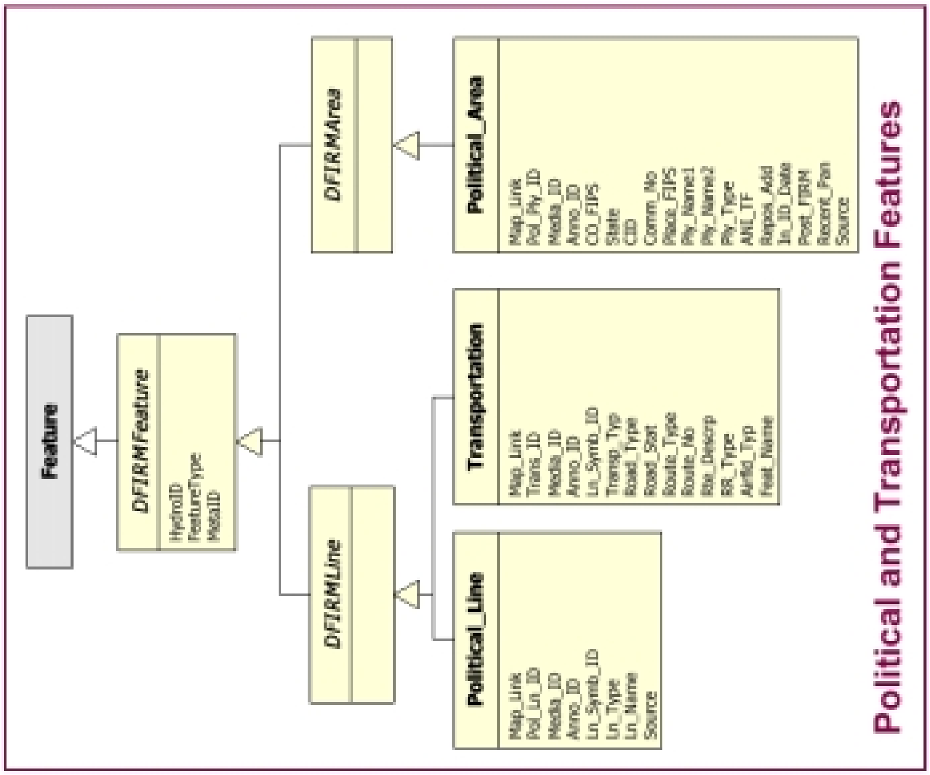
«CodedValueDomain»
FloodZone

+FieldType : <unspecified> = esriFieldTypeInteger
+MergePolicy : <unspecified> = esriMPTDefaultValue
+SplitPolicy : <unspecified> = esriSPTDefaultValue
+V : esriFieldTypeSmallInteger = 1
+VE : esriFieldTypeSmallInteger = 2
+A : esriFieldTypeSmallInteger = 3
+AE : esriFieldTypeSmallInteger = 4
+AO : esriFieldTypeSmallInteger = 5
+AOVEL : esriFieldTypeSmallInteger = 6
+AH : esriFieldTypeSmallInteger = 7
+A99 : esriFieldTypeSmallInteger = 8
+AR : esriFieldTypeSmallInteger = 9
+X : esriFieldTypeSmallInteger = 10
+X500 : esriFieldTypeSmallInteger = 11
+D : esriFieldTypeSmallInteger = 12
+A00IC : esriFieldTypeSmallInteger = 13
+500IC : esriFieldTypeSmallInteger = 14
+FWIC : esriFieldTypeSmallInteger = 15
+ANI : esriFieldTypeSmallInteger = 16
+Water : esriFieldTypeSmallInteger = 17
+Undes : esriFieldTypeSmallInteger = 18
+X500_Levee : esriFieldTypeSmallInteger = 19

Appendix D: Analysis Diagrams



Flood Data Features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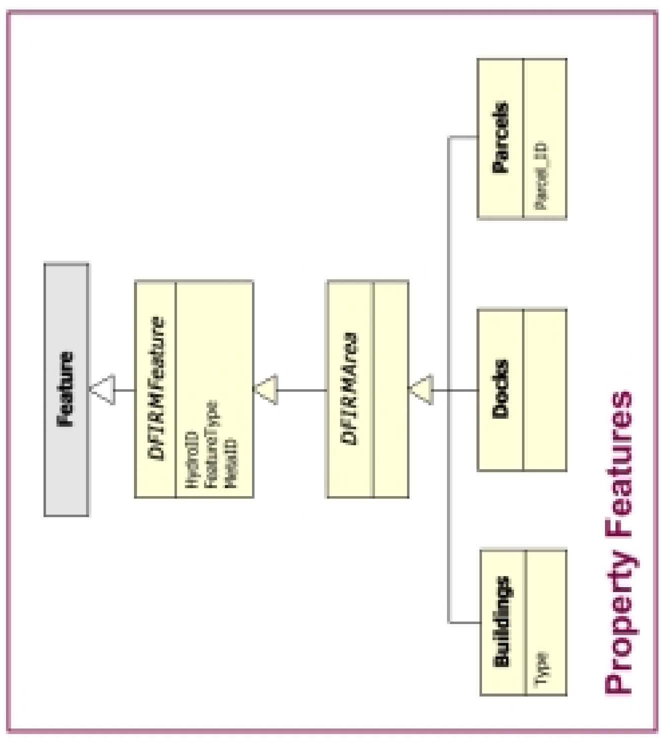
DFIRMFeature
HydroID
FeatureType
MetaID
DFIRMLine
DFIRMArea
Political_Line
Transportation
Political_Area
Political and Transportation Features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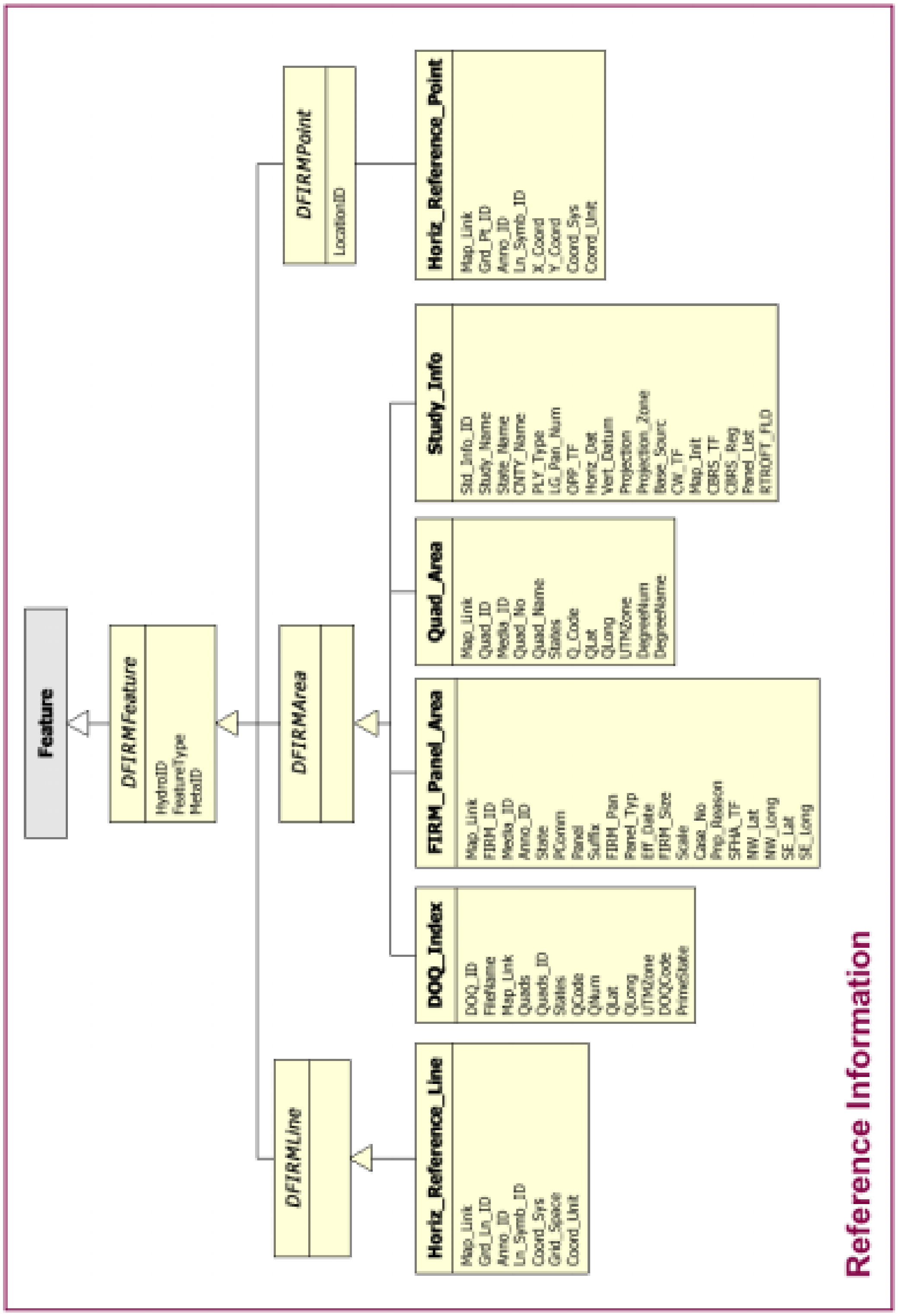
DFIRMFeature
HydroID
FeatureType
MetaID
DFIRMArea
Buildings
Type
Docks
Parcels
Parcel_ID
Property Features


Feature
DFIRMFeature
HydroID
FeatureType
MetaID
DFIRMPoint
LocationID
DFIRMArea
DFIRMLine
Horiz_Reference_Point
Map_Link
Grd_Pt_ID
Anno_ID
Ln_Symb_ID
X_Coord
Y_Coord
Coord_Sys
Coord_Unit
Study_Info
Std_Info_ID
Study_Name
State_Name
CNTY_Name
PLY_Type
LG_Pan_Num
OPP_TF
Horiz_Datum
Vert_Datum
Projection
Projection_Zone
Base_Sourc
CW_TF
Map_Init
CBRS_TF
CBRS_Reg
Panel_List
RTROFT_FLD
Quad_Area
Map_Link
Quad_ID
Media_ID
Quad_No
Quad_Name
States
Q_Code
QLat
QLong
UTMZone
DegreeNum
DegreeName
FIRM_Panel_Area
Map_Link
FIRM_ID
Media_ID
Anno_ID
State
PComm
Panel
Suffix
FIRM_Pan
Panel_Typ
Eff_Date
FIRM_Size
Scale
Case_No
Pnp_Reason
SFHA_TF
NW_Lat
NW_Long
SE_Lat
SE_Long
DOQ_Index
DOQ_ID
FileName
Map_Link
Quads
Quads_ID
States
QCode
QNum
QLat
QLong
UTMZone
DOQCode
PrimeState
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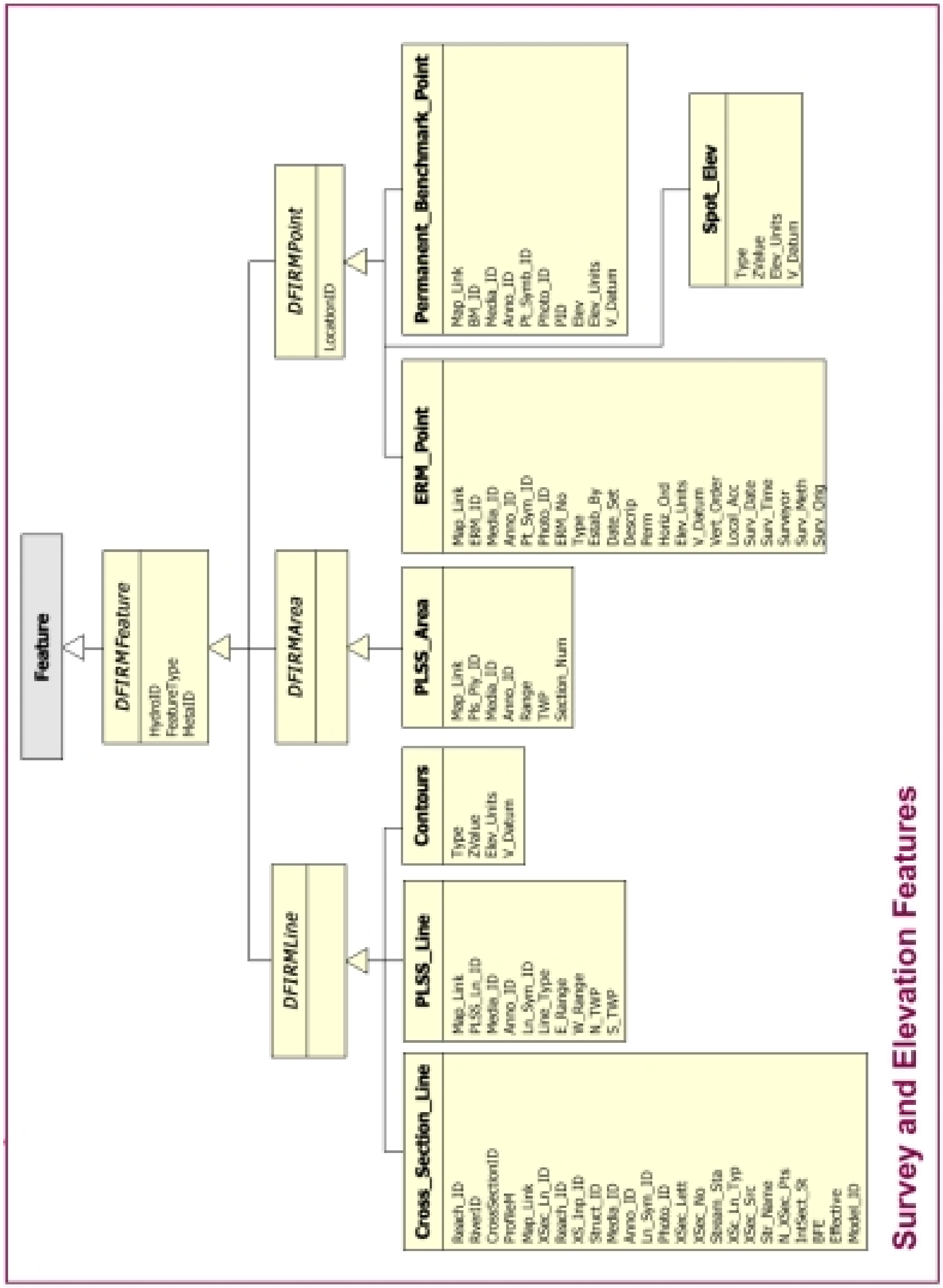
Map_Link
Grd_Ln_ID
Anno_ID
Ln_Symb_ID
Coord_Sys
Grid_Space
Coord_Unit
Reference Information


Feature
DFIRMFeature
HydroID
FeatureType
MeaID
DFIRMLine
DFIRMArea
DFIRMPoint
LocationID
Cross_Section_Line
Reach_ID
RiverID
CrossSectionID
ProfileM
Map_Link
XSec_Ln_ID
Reach_ID
XS_Inp_ID
Struct_ID
Media_ID
Anno_ID
Ln_Sym_ID
Photo_ID
XSec_Left
XSec_No
Stream_Sta
XSc_Ln_Typ
XSec_Src
Str_Name
N_XSec_Pts
IntSect_St
BFE
Effective
Model_ID
PLSS_Line
Map_Link
PLSS_Ln_ID
Media_ID
Anno_ID
Ln_Sym_ID
Line_Type
E_Range
W_Range
N_TWP
S_TWP
Contours
Type
ZValue
Elev_Units
V_Datum
PLSS_Area
Map_Link
Plc_Ply_ID
Media_ID
Anno_ID
Range
TWP
Section_Num
ERM_Point
Map_Link
ERM_ID
Media_ID
Anno_ID
Pt_Sym_ID
Photo_ID
ERM_No
Type
Estab_By
Date_Set
Descrip
Perm
Horiz_Ord
Elev_Units
V_Datum
Vert_Order
Local_Acc
Surv_Date
Surv_Time
Surveyor
Surv_Meth
Surv_Orig
Permanent_Benchmark_Point
Map_Link
BM_ID
Media_ID
Anno_ID
Pt_Symb_ID
Photo_ID
PID
Elev
Elev_Units
V_Datum
Spot_Elev
Type
ZValue
Elev_Units
V_Datum
Survey and Elevation Features

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